The development and effectiveness of a perceptual training programme for coaches and judges in gymnastics

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy by

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ABSTRACT

Jennifer Page: The development and effectiveness of a perceptual training programme for coaches and judges in gymnastics

This thesis investigated the development and effectiveness of a perceptual training programme for coaches and judges in gymnastics. Study one examined the variability of visual search for coaches and judges when viewing handspring vaults. The study found that there were no significant differences between the mean number of fixations, fixation duration and number of areas fixated across two time-points four weeks apart. In addition, the natural range of variation of the number of fixations, fixation duration, and number of areas fixated was found to be 9.7%, 5.7% and 14.2% (expressed as coefficient of variation). Study two examined differences between expert and novice gymnastic coaches' and judges' visual search. Analysis of gaze behaviour showed that experts make significantly more fixations of significantly longer duration to significantly fewer areas than novices. There was no significant difference between the outcome judgments made by the expert and novice coaches and judges. These findings suggest that visual search may be a contributing factor to expert performance in judgment formation. Study three explored the visual search patterns and knowledge used by expert coaches and judges when making decisions. Data were gathered through the use of eye-tracking and semi-structured interviews. Analyses established that experts tend to fixate on the torso and shoulders of gymnasts throughout the vault, and that there are three to four specific areas which are explored during each phase of a vault. Study four examined the effectiveness of a perceptual training programme for a perceptual training and control group. Fixation number, fixation duration, number of areas fixated and outcome judgment were recorded at baseline, immediately after the programme and four weeks after it had been withdrawn. 2 (control vs. perceptual training) x 3 (intervention phase) ANOVA's with repeated measures showed that the perceptual training group produced significantly less error at the retention stage for number of fixations (F (2,6) = 12.57, p = 0.01, effect size η^2 = .81), at the post-test for fixation duration (F (2,6) = 7.49, p = 0.02, effect size η^2 = .71), however post-hoc analyses could not detect the difference for number of areas fixated. In study five, four participants that took part in the experimental condition watched a perceptual training DVD twice a week for six weeks. The case study data showed that the expert and novices who watched the perceptual training DVD made changes to their visual search variables and judgments and therefore became more analogous to the experts from study three from baseline to the post-test. However, only the novices retained the beneficial effects of the intervention. To conclude, this programme of research examined the development and effectiveness of a perceptual training programme for coaches' and judges' in gymnastics. This thesis suggests that a perceptual training programme based on the visual search and declarative knowledge of expert coaches and judges is effective at altering visual search and enhancing decision making for novice coaches and judges. This research programme therefore promotes the use of perceptual training programmes for novice coaches and judges in sport.

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1.1 INTRODUCTION

The perceptual abilities of certain populations can improve through training (Adolphe, Vickers & Laplante, 1997; Franks & Miller, 1991; Harle & Vickers, 2001; Smyth, 1984). Whilst various methods of perceptual training have been used in the sport psychology literature, Farrow and Abernethy (2002) suggest that

“a logical point to start the search for the most effective means of developing perceptual-motor skill is by seeking a comprehensive understanding of the sources and mechanisms that underpin any expert advantage on the task of interest” (p.471).

Two pertinent mechanisms that distinguish between experts and novices are the knowledge structures stored by expert performers (Janelle & Hillman, 2003; Ste-Marie, 1999) and the resultant ability of expert performers to produce more refined visual search patterns (Helsen & Pauwels, 1992, 1993; Mann, Williams, Ward & Janelle, 2007; Savelsbergh, Williams, Van Der Kamp & Ward, 2002; Singer, Cauraugh, Chen, Steinberg & Frehlich, 1996; Vickers, 1996 a,b). Visual search is indicated by the number of fixations, fixation duration and fixation location produced by performers. A fixation refers to a time period of 120ms or above when a performer is focusing on one part of the display (Williams, Davids & Williams, 1999).

Of interest in this thesis is whether or not those involved in training decision making are able to use experts’ knowledge and visual search patterns to perceptually train novice and expert populations in order to produce more accurate decisions. Of particular interest is whether a perceptual training programme results in advantageous adaptations to visual search and decision making. With reference to the coach and judge populations, their role is to produce an accurate judgment with regards to an observed performance. Sports performers, however, are required to produce a physical performance as well as make decisions. Judgments are defined as “a set of evaluative and inferential processes that people have at their disposal and can draw on in the process of making decisions” (Koehler & Harvey, 2004, preface xv).

Understanding how expert judges and coaches form judgments is important given that a third of all sports recognised by the International Olympic Committee (IOC) are considered to have a performance rating system in which judging plays a major role (Stefani, 1998). This is a contemporary topic given the judging discrepancies in the Olympics made by expert judges who had substantial experience in judging. Specifically in the 2004 Olympics the gymnastics judges made a marking mistake which cost South Korea's Yang Tae-young a gold medal in the men's all-round event. Adrian Stoica, head of the International Gymnastics Federation (FIG) men's technical committee in 2004, put out a statement in support of the judges suggesting that "Just like gymnasts are human and can make mistakes, judges are also human and can make mistakes” showing the difficulties that face judges in these conditions. Given these difficulties, it is important to understand the mechanisms that underpin expert judgments.

1.2 STATEMENT OF THE PROBLEM

Although perceptual training has been investigated in the literature there is dispute over how it should be best applied to have the greatest positive effect on sporting performance (Williams & Grant, 1999). Specifically, much of the research has examined the impact of perceptual training on variables such as anticipation (Abernethy, Wood & Parks, 1999; Christina, Baressi & Shaffner, 1990; Hagemann, Strauss, & Cañal-Bruland, 2006; Singer, Cauraugh, Chen, Steinberg, Frelich & Wang, 1994; Williams & Burwitz, 1993) and decision making (Burroughs, 1984; Caserta, Young & Janelle, 2007; Damron, 1955; Haskins, 1965; Londeree, 1967) without empirically testing mechanisms through which perceptual training is effective. Additionally, Abernethy (1996) suggested that understanding how best to train perceptual and decision making skills for sport is hampered by a shortage of well-controlled training studies. Despite this paper being published 12 years ago this gap in the literature has still not been addressed. Therefore studies empirically investigating the mechanisms by which perceptual training programmes are effective, using longitudinal designs, would be a valuable addition to the literature.

The studies that have investigated some of the proposed mechanisms that underpin effective perceptual training programmes such as visual search have not considered whether these mechanisms are stable before they attempt to manipulate them. Therefore it is important to identify prior to manipulation whether the proposed mechanisms by which perceptual training might work are stable. Study one therefore aims to investigate how consistent the visual search of gymnastics coaches and judges is, when watching identical performances four weeks apart.

Once the consistency of visual search of gymnastics coaches and judges has been established, it is important to identify whether visual search is a factor that contributes to expertise in decision making. If visual search is similar between experts and novices then arguably it may not be a factor that needs training. Study two therefore investigates whether there are differences between expert and novice gymnastics coaches and judges visual search patterns and outcome judgments when viewing handspring vaults.

Study three aims to examine, in detail, the visual fixations and declarative knowledge used by expert gymnastics coaches and judges to analyse performance at the different phases of a handspring vault. This study will combine visual search procedures with verbal report data, through semi-structured interviews using a temporal analysis, in order to obtain information that will enable the development of coherent perceptual training aids. The temporal analysis will include investigating the five main phases of the handspring vault. Following the guidelines from British

Gymnastics the five stages include: the run up, hurdle step, first flight, second flight and landing, these stages are discussed in greater detail in chapter six.

Most importantly, the final study of this thesis will examine the effectiveness of the perceptual training DVD developed from the data in study three. Effectiveness will be assessed through adaptations in visual search and accuracy of the judgments made by the gymnastics coaches and judges from baseline to immediately after the intervention, and four weeks post intervention.

1.3 AIMS OF THESIS

1. To determine whether visual search is consistent for both coaches and judges in gymnastics.
2. To examine differences between expert and novice gymnastics coaches' and judges' visual search and judgments.
3. To determine what visual information and declarative knowledge is used by expert gymnastics coaches and judges to produce judgments.
4. To examine the impact of a perceptual training programme on gymnastics coaches and judges.

1.4 HYPOTHESES

Study 1

1. The number of fixations, fixation duration and number of areas fixated by gymnastics coaches and judges will be consistent when they view two identical performances of handspring vaults four weeks apart.

Study 2

2. Expert coaches and judges will produce significantly fewer fixations, of significantly longer duration to significantly fewer areas than novice coaches and judges when judging handspring vaults.

Studies 4 and 5

3. The perceptual training aid developed from the data in study three will have a greater impact on number of fixations, fixation duration, number of areas fixated and accuracy of judgment than the control DVD.

Review of the Literature

This chapter aims to inform the reader of the key factors that underpin this thesis. Central to this programme of research are the concepts of decision and judgment formation, attention, visual search and perceptual training. Relevant theories and research relating to each of these areas will be examined.

2.1 DECISION MAKING AND JUDGMENT THEORY

2.1.1 Social cognitive perspective

A third of all sports recognised by the IOC are considered to have a performance rating system in which judging plays a major role (Stefani, 1998). It is readily apparent that observers in sport such as coaches, judges and officials seem to be able to make subjective judgments of motor performances efficiently and accurately based on observations. Judgments are defined as “a set of evaluative and inferential processes that people have at their disposal and can draw on in the process of making decisions” (Koehler & Harvey, 2004, preface xv).

The social cognitive perspective of judgment follows an information processing framework. Firstly, the social cognitive perspective investigates how social information is perceived from the display. Secondly, it describes how information is encoded, transferred to and recalled from memory. In its entirety, it attempts to explain what processes are involved when people make judgments, attributions and decisions (Bless, Fiedler & Strack, 2004). A pictorial representation of the sequence of social information processing can be seen in Figure 2.1.

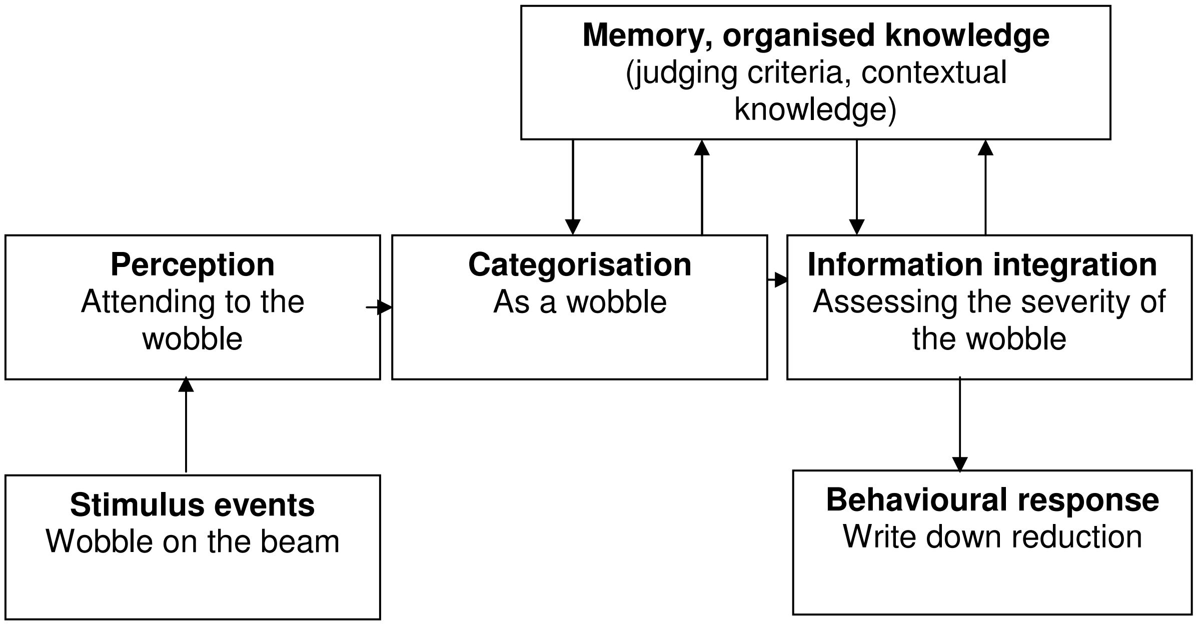

Figure 2.1. The sequence of social information processing (Bless et al., 2004) applied to the example of a gymnastics judging task.

The specific stages of social information processing suggest that perception precedes decision and action. Perception is related to coaches' or judges' requirements to perceive the spatio-temporal structure of the environmental information in order to successfully produce a judgment. It is therefore logical to suggest that visual information is an important source on which coaches and judges rely. Perception has been a focus within the sports science literature through the mechanism of visual search patterns, which are thought to represent elements of a performer's perceptual strategy (Moreno, Reina, Luis & Sabido, 2002). Expert - novice differences in visual search have been found in various studies (reviewed in sections 2.6.2.1, 2.6.2.2 & 2.6.2.3) and, therefore perceptual strategy and visual search are a central focus of this expertise based thesis. Once the perception process is functioning it provides the necessary stimulus for the release of a specific programme of action.

However, as the role of coaches and judges is based on error detection rather than movement, the focus is primarily on the decision making components rather than the initiation of a stored motor programme. Using the sequence suggested by Bless et al. (2004), the decision making components such as categorisation (what is happening) and information integration (how should it be classified), are informed by contextual knowledge. There has been extensive literature documenting the differences between expert and novices knowledge (MacMahon & Ste-Marie, 2002; Paull & Glencross, 1997; Ste-Marie, 1999, 2000), and therefore the knowledge base of experts is central to this thesis as a source of training information. The differences in visual search and stored knowledge between expert and novices would suggest that there is perhaps a relationship between them, and top-down models such as the information processing model (Welford, 1968) support this. Information processing theory suggests that stored knowledge held in long term memory (LTM) guides the attentional process towards areas of the display (Welford, 1968), which will determine the visual search strategy.

The implication from social information processing theory is that expert coaches and judges have different stored knowledge from novices. This may result in different visual search patterns, which may help them to make more accurate judgments, resulting in enhanced expertise. McPherson and Kernodle (2003) suggest that experts develop ‘action plan profiles’ that enable them to generate more appropriate strategic decisions. For example, the action plan profile might determine that if a gymnast has bent legs then 0.3 points must be deducted. Relevant literature and supporting theoretical underpinnings for expert judgments are explored in sections 2.3.1, 2.4.1.1, 2.4.1.2 and 2.4.1.3. When this framework is applied to the judgment of sport performance, it becomes obvious that inaccurate judgments can result from small errors or incorrect information from different stages of the information processing process (Plessner, 2005). This indicates that various aspects involved in information processing need to be explored to fully understand the differences between the judgments of experts and novices.

2.1.2 Judgments in the roles of coaches and judges

Subjective sports such as gymnastics involve coaches and judges watching performers complete complex movement patterns. The coaches and judges therefore engage in extensive information processing related to the movement patterns observed (Ste-Marie, 1999). Simmons and King (1994) identified three steps for observing and analysing a motor performance. The first step requires attention to and perception of movement performance, similar to the perception stage of the social information processing sequence suggested by Bless et al. (2004). Perception involves the selective gathering of visual information and is therefore important for both coaches and judges in performance analysis.

From this observation, a number of critical features need to be compared to a conceptualised desirable movement so that similarities and differences between the observed and conceptualised performance can be identified. This second stage is supported by the categorisation and information integration stages by Bless et al. (2004). This comparison, between what the moves should look like and what they do look like would be important for coaches and judges when analysing performance as discrepancies may indicate errors in the performance. The final stage identified by Simmons and King (1994) suggests that based on this comparison, diagnosis of the causes of the differences between observed and desired performances is needed. However, this would only be important for coaches whose particular role is to correct performance, rather than judges whose role is to make immediate use of decision making processes and translate the information in terms of deviations from an established code (Bard, Fleury, Carriére & Hallé, 1980).

In essence, gymnastics coaching and judging requires stored memory of gymnastic elements, divided and selective attention as well as detection and identification of complex movement patterns (Ste-Marie, 1999). Judges and coaches therefore need to know what it is they should attend to and then process this effectively in order to perform their roles. Differences in their information processing in terms of their stored knowledge, resultant visual search patterns, and the interpretation of information may explain any discrepancies seen within the judging of performance.

Plessner and Haar (2006) suggest that judgments are typically concerned with one of three judgmental dimensions: evaluative judgments, judgments of identification, and judgments of cause. Evaluative judgments are formed when performance is judged on a good-to-bad scale, which would require pre-determined criteria stored in LTM. An example of an evaluative judgment in sport would be ‘that was a good handspring vault’. Judgments of identification are related to the consequences of an action, for example a gymnastics judge recognising that a wobble on the beam is a pre-requisite of deducting a specific number of points. Judgments of cause (causal attributions) relate to when people make judgments about the contribution of potential factors that led to certain outcomes (Plessner & Haar, 2006), for example ‘that gymnast won the competition because she performed last in the competition’. Perhaps most important for this thesis are evaluative judgments and judgments of identification. This is because coaches and judges are required to observe a performance and give it a value based on pre-determined criteria. These are therefore the key tasks for the participants involved in the four interlinking studies within this thesis.

Many studies have concluded that experts have enhanced perceptual-cognitive skills (Mann et al., 2007). Differences between expert and novices have been documented in pattern recognition (Allard, Graham & Paarsalu, 1980), cue utilisation (Savelsbergh et al., 2002), and their ability to assign accurate probabilities to events (Ward & Williams, 2003).

Potential differences between experts and novices can be explained through differences in stored knowledge in LTM.

2.2 USE OF KNOWLEDGE

When observing (acquiring sensory information) in a predictable environment, it seems likely that object search mechanisms will take advantage of previous knowledge (Bless et al., 2004; Chun & Jiang, 1998; Oliva, Wolfe & Arsenio, 2004). This knowledge will serve as a source of top-down guidance (Chun & Jiang, 1998; Wolfe, 1994; Wolfe, Cave & Franzel, 1989), directing attention to the likely locations of the desired object. There are many types of knowledge that can be stored in LTM and this section aims to identify types of knowledge that may relate to coaching and judging expertise.

2.2.1 Types of knowledge

Cognitive structures relate to the knowledge base of judges and coaches. Knowledge is commonly categorised into declarative, procedural, strategic (Thomas, 1994; Thomas & Thomas, 1994) and contextual knowledge (Chun & Jiang, 1998). Declarative knowledge (also known as semantic knowledge (Moran, 1996)) is the “knowledge about factual rule-based information” (Ste-Marie, 1999, p.271) and for coaches and judges relates to the specific guidelines and criteria for performing gymnastics routines. Procedural knowledge pertains to “how to do something within a specific domain, serving as the link between action and involves the decision of what movement to execute and its subsequent execution” (Ste-Marie, 1999, p.271). Procedural knowledge may be more useful for coaches and performers, whose primary role is to correct movements, thus knowing how to perform each element will undoubtedly aid performance. Strategic knowledge refers to “concepts and strategies of generalisable form that can be applied within a variety of domains, including different control processes used to remember information” (Ste-Marie, 1999, p.271). Ste-Marie (2003) acknowledges that a representative task for strategic knowledge has not been investigated within judging populations because judges of one sport tend not to judge other sports, and as such transfer of basic rules or strategies across contexts may be of limited interest to researchers. Contextual knowledge refers to the knowledge that is learned, often implicitly, regarding the learned associations between the target location and contexts, and as a result can help guide spatial attention (Chun & Jiang, 1998). In relation to coaches and judges, contextual knowledge will serve as the link between knowing what the essential visual cues are within the display (e.g., gymnasts hips) and the interpretation of the visual cues, either though a point's deduction or through correcting the movement.

Many studies have suggested expert referees, coaches, and athletes have superior knowledge of rules and signals, suggesting increased declarative knowledge. For example, Ste-Marie (1999) found that expert gymnastic judges demonstrated superior declarative knowledge to novice level judges. In a later study Ste-Marie (2000) found that novice judges spent more time looking at the scoring paper suggesting a lack of easily accessible declarative knowledge. Interestingly, MacMahon and Ste-Marie (2002) found that expert rugby referees used more semantic information suggesting increased contextual knowledge. Additionally, Côté, Salmela and Russell (1995 a,b) conducted two studies, one investigating training and competition considerations and another examining methodological frameworks of gymnastic coaches' knowledge. Interestingly, within the methodological framework study (Côté et al., 1995a), contextual information was cited as a way of developing elite athletes; this implies that the inclusion of contextual information in LTM contributes to the coaching process.

Ste-Marie (1991) examined the sport-specific cognitive attributes that were predicted to lead to an expert advantage in gymnastic judging and found that expert gymnastics judges showed significantly greater depth and breadth in their declarative knowledge base. These research papers along with other non-sport research all support the notion that experts have access to a more complete store of declarative, procedural (Chi, Feltovich & Glaser, 1981; Gobbo & Chi, 1986) and contextual knowledge (MacMahon & Ste-Marie, 2002). The above findings suggest that declarative and contextual knowledge may be fundamental for improving expert judgments in sport. An advantage of having enhanced procedural and declarative knowledge may be that it guides visual attention in a more selective manner through top-down cognitive processing.

In a sporting environment there are almost an infinite number of possible objects of visual attention. Ste-Marie (2000) utilised an observation based design to study expertise in gymnastic judging. Ste-Marie found that novice judges spent less time looking at the gymnast perform, spent more time looking at the scoring paper, and were less able to engage in the dual-task demands required in gymnastic judging, compared to expert judges, showing an inability to cope with excessive information processing demands. This suggests that novice gymnastics judges attend to what might be referred to as irrelevant cues such as the scoring paper. As the visual system cannot fully process all input, the visual system can adapt in two ways. The first is to discard input at the periphery, and the second is to process information selectively (Wolfe, 1994). Such selectivity can be explained though parallel and serial processing.

Parallel processing is the ability to process several bits of information simultaneously, whereas serial processing is more attention-demanding and involves processing one bit of information at a time in a sequential manner (Wolfe et al., 1989). Neisser (1967) suggests that parallel visual processing operates over large portions of the visual display at one time. During this stage objects are detected using peripheral vision and this process is thought to be non-attention demanding (Williams et al., 1999). Neisser (1967) also suggests that there is a second set of limited-capacity processes that are restricted to a smaller portion of the visual field selecting only relevant information. This stage is thought to be attention demanding and involves bringing the stimuli into the more sensitive foveal region of the retina (Williams et al., 1999). This suggests that parallel processing is followed by serial processing. Neisser (1967) suggests that in order to cover the full visual field the limited capacity processes must be deployed serially from location to location. The concepts of parallel and serial processing are further explored through the search models in section 2.2. The control of serial processing can be based on endogenous factors such as the knowledge stored in LTM and is best explained through Norman's pertinence model (Norman, 1968) which suggests that information is filtered late in the information processing chain and contextual cuing theory (Chun & Jiang, 1998, 1999, 2003) which suggests that that learned associations between the target location and contexts, stored as contextual knowledge in LTM, will guide spatial attention towards the task relevant aspects of a scene.

Norman (1968) model of selective attention attempts to explain the mechanisms by which individual can filter out information to aid the decision making process. Norman (1968) proposed that attention has a fixed capacity and suggested that filtering of information occurs subconsciously late in the information processing procedure, after information is perceived or after it has been processed cognitively. Norman suggested that all signals arriving at the sensors, including visual sources, pass through an early stage of analysis performed by physiological processes. The parameters extracted from these processes are used to determine where the representation for the sensory signal is stored in memory. Consequently, Norman (1968) suggested that all sensory signals excite their stored representation in memory subconsciously, with no demand on the processing capacity. In parallel, an examination of previous signals in the LTM occurs which establishes a class of events deemed to be pertinent to the ongoing analysis. Most significantly, this theory suggests that through learning performers build up a pool of experience in the LTM used subsequently to interpret similar events. Information that is most highly excited by sensory and pertinence inputs will be selected for further analysis and therefore aid (selective) attention. This should aid the decision making process which will impact upon the behaviour of the individual. Therefore logically, through experience, sports people will know the important contextual cues within the display stored within the LTM, and will therefore only attend to the relevant ones.

This process relies heavily on input from short term memory (STM) and LTM stores to allow a reference point which provides identification of what is pertinent and irrelevant (or redundant) to the individual. Expert judges, for example, may know from experience that the shoulders provide information about the speed that a gymnast is running, thus when the eyes process shoulder information through parallel search, it should excite the pertinence inputs resulting in directing serial attention to the shoulder region.

Subsequent models of search have attempted to describe the processes by which people are able to guide attention in relation to familiar dynamic displays. Chun and Jiang (1998) suggest that "coherent, semantically related visual context can facilitate the detection and identification of component objects and events" (p.30). This implies that contextual knowledge relating to the display can aid the process of search through the learned associations between the target locations and the context (Chun & Jiang, 1998). Evidence for this phenomenon was found in a series of experiments presented by Chun and Jiang (1998, 1999, 2003). Such empirical research indicates that learned associations between the target location and contexts, stored as contextual knowledge in LTM, will guide spatial attention towards the task relevant aspects of a scene. Furthermore, seeing a familiar context has been shown to automatically activate the representations of consistent objects within the scene as well as their locations (Biederman, Mezzanotte & Rabinowitz, 1982; de Graef, Christiaens & d'Ydewalle, 1990; Henderson & Hollingworth, 1999).

Findings suggest that when observers search for an object that is contextually consistent with the environment their eyes fall on the object faster than when they are searching for a contextually inconsistent object (Henderson, Weeks & Hollingworth, 1999). Therefore, when viewing a series of gymnastics vaults, one would expect trained coaches and judges to be able to perform rapid search, since the scene and context is something they are familiar with. In addition, Hollingworth and Henderson (2002), and Hollingworth, Williams, and Henderson (2001) concluded that when observers explore a scene, details of information about previously fixated objects are retained in LTM and used to plan further exploration of the image. Thus, previous fixations held in LTM by coaches and judges should guide future search processes to similar locations within the scene.

The limited number of research studies investigating gymnastics coaches' and judges' knowledge (see Ste-Marie 1991, 1999, 2000 for exceptions) presents a problem for those interested in training coaches and judges. Further studies in this area mapping knowledge bases of experts could help develop understanding of the processes involved in expert judgments. Interestingly, research has been conducted into the resultant visual search of gymnastics coaches and judges. However, before this specific research is discussed it is important to understand how someone may visually search for information in a complex environment.

2.3 SEARCH THEORY

Visual selective attention theory concerns "the role of vision in motor skill performance, specifically in directing visual attention to environmental information that influences the preparation and, or, performance of an action" (Magill, 2001, p.128). The processes by which people orient their attention have been the focal point of many attention-based theories.

2.3.1 How attention may be directed

Eriksen and Yeh (1985) and Eriksen and St. James (1986) suggested that selective attention is based on a spotlight metaphor (Cave & Bichot, 1999; Moran, 1996), in which a mental beam illuminates a given target either internally or to an external cue. The spotlight is said to "enhance the efficiency of detection of events within its beam" (Posner, Snyder & Davidson, 1980, p. 172). As such, knowing the relevant cue(s) stored in LTM will allow performers to move the central beam of their spotlight in order to attend to what is relevant. Alternatively Eriksen and St. James (1986) proposed the zoom-lens model which suggests that attention is directed to a given area of the visual field but the span of this area can be increased or decreased as necessary.

Both, Easterbrook (1959) and LaBerge (1983) found evidence that supported the zoom-lens model through a series of experiments showing that participants could indeed adjust their attentional beam based on the demands of a task. Additionally, Nougier, Azemar, Stein, and Ripoll (1992) proposed that participants who practise playing tennis have the ability to diffuse attend rather than focally attend and are therefore able to increase the span of attention beam without a significant decrease in their performance. Both the zoom-lens model and the spotlight metaphor suggest that attention is limited to one area of a visual field at a time and are therefore based on serial processing. The role of serial processing for coaching and judging therefore is assumed to highlight the relevant cues that will enhance decision making (Eriksen & St. James, 1986; Posner et al., 1980).

Most of the information that must be processed and responded to by athletes is gathered through visual sensation and perception (Abernethy, 1991). The ability to highlight relevant cues (through a spot light or zoom lens) is dependent on a number of factors such a number of allocatable resources, background noise, use of advanced cues, and pattern recognition. The theories underpinning these processes are described below.

2.3.1.1 Allocatable resources

Kahneman (1973) argued that capacity of attention should not be considered as fixed as it changes as the requirement of the task alters. Kahneman (1973) proposed that as the difficulty of two simultaneous tasks increased more attentional capacity would be made available. Kahneman (1973) proposed that individuals could carry out two tasks providing they had enough allocatable resources in the Central Nervous System (CNS) to effectively perform the tasks, after which time maximum capacity would be exceeded and performance would deteriorate. Kahneman (1973) proposed that the allocation of resources was determined by two main factors; enduring dispositions and momentary intentions. Enduring dispositions are the rules of involuntary intention and are viewed as automatic responses where the performer's attention is directed towards anything unusual or different in the environment (Kahneman, 1973). Momentary intentions are the instructions given to an individual to help them maintain attention on correct cues (Kahneman, 1973). These ideas are aligned to the pertinence factor suggested by fixed capacity theorists (e.g., Norman, 1968) and suggest that attention is guided towards what is perceived as important (momentary intentions). Coaches and judges should therefore be able to carry out their role in performance evaluation providing that the task does not exceed their attentional capacity. In this instance the harder the task that they are doing (e.g., scoring a complex vault), the more attentional capacity should be available.

2.3.1.2 Signal detection

Another theory that aims to explain the process by which individuals are able to direct the visual system is the signal detection theory (Green & Swets, 1966; Swets, 1964). This theory aims to explain how skilled performers are better at detecting the presence or absence of a sensory signal within a visual display (Williams et al., 1999). It is based on the notion that the probability of detection of a stimulus depends on intensity of a signal relative to the background noise (McMorris, 2004). Factors suggested to affect our ability to detect a signal include bias and arousal. For example, a judge might be aware that a certain gymnast bends their arms normally so are drawn to that area (bias). Alternatively if arousal is low signals may be missed (omission) i.e., a judge might not see a gymnast's bent arms, whereas if arousal is too high judges may perceive a signal when one does not exist (commission) i.e., they might see bent arms when actually the arms were straight. These ideas are aligned to theories of arousal and anxiety (Easterbrook, 1959; Eysenck & Calvo, 1992; Janelle, 2002; Janelle, Singer & Williams, 1999).

In support of signal detection, Allard and Starkes (1980) required volleyball players and non-players to detect the presence of a volleyball in tachistoscopically presented slides of game and non-game situations. Results showed that there were no significant differences in accuracy of detection between players and non-players. However, in general, players were faster in responding to the slides, suggesting an enhanced ability to detect context relevant information. Allard and Starkes (1980) examined the processes that underpinned the enhanced perception and found that volleyball players produced rapid visual search for the ball, and ignored other contextual information. This perhaps suggests that volleyball players are able to quickly detect the ball through focusing their spotlight in that region within the display. Starkes (1987) later went on to examine whether the findings would be replicated in invasive team games. Starkes (1987) found no significant differences in decision speed, suggesting that rapid visual search does not underpin skilled performance in hockey. Bourgeaud and Abernethy (1987) corroborated these findings, but suggested that expert superior recall was only present when viewing video presentation rather than slides. Problems therefore exist when drawing conclusions from these studies, given that many of them have utilised static tachistoscopic slides. In reality, the scene would be dynamic and performers would be able to see the action sequence evolve and make use of contextual information (as suggested by contextual cueing theory) and situational probabilities to anticipate future ball detection (Williams et al., 1999).

2.3.1.3 Advanced cue utilisation and pattern recognition

The ability to pick up early cues and perceive a signal from only partial information has been shown in the literature to help sports performers anticipate (Abernethy & Russell, 1987; Mori, Ohtani & Imanaka, 2002; Singer et al., 1996; Williams & Davids, 1998). The majority of this research is interactive fast-ball sport related. With regards to gymnastics research, Ste-Marie (1999) found that expert judges were significantly better at anticipating up-coming elements than novices when using a temporal occlusion technique. Temporal occlusion refers to selectively editing film footage or real life displays at different points in order to give the participant variable extents of information (e.g., occluded prior to contact, at contact, or following contact; Williams et al., 1999). However, coaches and judges in gymnastics are able to see the whole movement, and although they are required to make a response quickly based on the quality of the movement, it is not under the type of time pressure, for example, that is faced by those involved in fast ball sports. Despite this, it should be noted that Ste-Marie (1999) found that when judges were able to perceptually anticipate from early cues in a sequence more accurate evaluation of the subsequent performance resulted. However, Ste-Marie (1999) did not investigate vaulting and therefore the importance of anticipating in the judging of this event has not been established.

With regard to pattern recognition, the key findings suggest that experts are able to recognise and recall structured patterns of play more accurately than novices (Williams, Ward & Smeeton, 2004). Allard et al. (1980) presented skilled and non-skilled basketball players with 80 slides containing both unstructured and structured patterns of play. The results suggested that skilled players were more accurate in recognising structured slides of set basketball plays than non-skilled basketball players. These findings have been replicated in other team sports such as soccer (Williams & Davids, 1995; Williams, Davids, Burwitz & Williams, 1993) and American football (Garland & Barry, 1991). With regards to gymnastics coaches, Imwold and Hoffman (1983) found that experienced coaches were able to recognise more static traces from previous viewed film footage than school teachers and undergraduate Physical Education students. This suggests that those with experience of gymnastics are better able to recognise performance. However, there has been no research that has proposed differences between expert and novice coaches or judges recall.

In summary, attention is influenced by a number of factors, including the number of allocatable resources available to the CNS. If through task demands judges or coaches have enough resources available then their ability to make accurate judgments should remain stable. Additionally, expertise can be explained through the experts' ability to detect relevant cues, recognise and recall patterns, and attend to early cues. To understand the impacts of these factors on attention, the theories of guided search must be considered.

2.4. THEORIES OF GUIDED SEARCH

2.4.1 Treisman's Feature Integration Theory

In the 1980s, Treisman and colleagues (Treisman, 1988; Treisman & Gelade, 1980) introduced the Feature Integration Theory (FIT), a visual search model that purported two differing visual search stages, parallel search and serial search. The FIT suggests two attentional stages. Firstly the pre-attentive stage (or parallel stage) detects simple feature aspects of the scene, such as edges, orientation, width, size, colour, brightness, and movement direction which forms a feature map. This map is then used to inform an activation map that guides the serial search process. For these basic features to be perceived as objects in the world they have to be `integrated' in the attentive stage and serial search is the result. This enables a conjunction search which is essentially based on targets that are defined by two or more basic features. The resultant serial search process checks the total amount of activity anywhere in a feature map. How efficient the search process is will depend on many factors including whether the target is defined, the similarity of the distractors and target, the nature of the distractors (e.g., whether they are all the same or different) and the size of the distractors.

For judging in gymnastics, it is assumed that experts know what to look for and are therefore searching for a defined target (e.g., the gymnast's hips) within a variety of distractors (e.g., legs, arms). In parallel visual search, the object is considered to be significantly different to the distractor (e.g., in colour, brightness, or size) and all objects can be processed at the same time in order to identify the target (pop-out). The FIT suggests that if features are detected in the parallel search then flat visual slopes will be produced indicating very quick search times. Detecting these features will not be affected by the display size presented to the participants. For example if participants are searching for a red square amongst blue squares, it would not matter how many blue squares there were, the participants would be able to detect the red square quickly, indicating a quick search time. Alternatively, serial search occurs when that object is not significantly different from the distractors (e.g., in shape and/or size) and each object has to be attended to separately (selective attention). Detecting these features will be affected by the display size presented to the participants. For example if participants are searching for a red square amongst red rectangles, the more red rectangles there are in the display the longer the search would take. This serial process is caused by increased decision noise and results in increased search time and therefore steeper visual slopes.

2.4.2 Wolfe's Guided Search Model

Wolfe and colleagues aimed to modify Treisman's FIT (Cave & Wolfe, 1990; Wolfe & Cave 1989; Wolfe et al., 1989), and originally proposed the Guided Search Model (GSM). The GSM assumes that the early stages of the visual system processes all locations in parallel but are capable of extracting only a limited amount of information from the visual input. The information that is summed across features to create an activation map that includes the system's best guesses about the location of a target item. The activation maps that are summed come from bottom-up properties of the display such as unusual features and from the participant's top-down knowledge of the demands of the task. The bottom-up activation is the measure of how unusual something is in its present context, whereas the top-down activation is more user-driven through the use of stored knowledge. The activation map aims to direct attention to the locus of highest activation.

The model suggests that subsequent processes can perform other more complex tasks but are limited to a very restricted number of spatial locations at one time and therefore attention is deployed in a serial manner until the target item is either found, or until no likely target items remain. A key difference between the models is that Treisman (1988) labels the initial stage as parallel search, whereas Wolfe labels it efficient search. However they are both referring to the initial parallel processing stage of search. In addition the second stage is termed as serial processing by Treisman, and less-efficient search by Wolfe. Wolfe (1994) later proposed a revised GSM (GSM 2.0), which aimed to explain a continuum, rather than the serial / parallel dichotomy described by Treisman and the earlier GSM. With reference to the two models a number of conclusions can be drawn. The first is that flat slopes are a result of parallel or efficient search. The second is that serial or non-efficient search results in steeper slopes. The third is that the more similar the target and distractors are the more inefficient the search will be.

2.4.3 Summary of search models

These traditional models of visual search have identified two types of search. Feature search take place when the target is defined by one basic feature, whereas conjunction search include searching for targets that are defined by two or more basic features (Wolfe & Gancarz, 1996). In sport conjunction search is required, because many target cues will be of specific colour and form. Conjunction search is said to be less efficient as it requires serial processing and self-terminating search, and it is affected by 5-10ms for every additional distractor. The reaction time in sport (indicted by the depth of the visual slopes, see section 2.4.1) will vary depending on how much distractors have in common with the target. Also, because sport is often reliant on the spatial arrangements of features, rather than colour or form, search will often be inefficient. If performers are able to group distractors then search efficiency can increase. It is generally agreed that conjunction targets of two or more elements are harder to detect than feature elements, however this does not always result in steeper slopes or serial search. The models presented in section 2.4.1 and 2.4.2 investigating visual search, however, do not deal with the live, fast and dynamic situations seen by sports coaches and judges, and therefore the application of such models is limited. More recently, visual search has been measured using eye-tracking systems rather than visual reaction time to enable a more in-depth analysis of perceptual expertise.

2.5 VISUAL SEARCH RESEARCH FINDINGS

2.5.1 Non-sport findings

Perhaps the first well-known use of eye trackers in the study of human (overt) visual attention occurred during reading experiments (Duchowski, 2002). More recently eye-tracking research has focused on industrial engineering. Such research was aimed at enabling pilots to guide weapons by selecting targets with their eyes. Existing research has found that eye-tracking is invaluable in designing environments such as aircraft cockpits (Derefeldt, Skinnars, Alfredson, Eriksson, Andersson, Westlund et al., 1999), and air traffic control stations (Fitts, Jones & Milton, 1950) where the operator has to remain in a confined position to control a device, often with a high level of stress. In addition to the industrial engineering based research, visual search has also been of interest to doctors.

In a review of expertise in visual diagnosis of X-rays and skin disorders, Norman, Coblentz, Brooks, and Babcook (1992) found modest increases in accuracy of diagnosis for representative X-rays beyond that of medical residents with more than one year of daily experience with X-ray diagnosis. Lesgold, Rubinson, Feltovich, Glaser, Klopfer, and Wang (1988) and Wolf et al. (1994) found distinctly superior performance by experts only on difficult cases of X-ray diagnosis, suggesting that training effects contribute to performance of complex tasks. Norman, Rosenthal, Brooks, Allen, and Muzzin (1989) found that the accuracy of diagnosis increased uniformly as a function of expertise over both easy and difficult cases for detection of skin disorders. Lesgold et al. (1988) were able to study expert radiologists' construction of an integrated mental representation of X-rays for complex cases using a verbal report protocol. Lesgold et al. (1988) suggested that experts were able to incorporate unusual features into their mental representation, such as dislocation of organs due to previous surgery, and other information about the patient's clinical history. Increased expertise in visual diagnosis appears to be associated with more rapid perceptual identification of abnormal features at presentation times of 0.5s (Myles-Worsley, Johnston & Simons, 1988) and 2.0s (Lesgold et al., 1988). When related to sport this suggests that expert coaches and judges may be quicker at identifying unusual techniques used by gymnasts.

Leong, Nicolaou, Emery, Darzi, and Yang (2007) examined whether experience improved the consistency of visual search behaviour in fracture identification in plain radiographs, and the effect of specialization. They found that expert search behaviour exhibited higher accuracy in identifying fractures when they existed. In addition the consultant radiologists' eye tracking patterns were more consistent than the accident and emergency senior house officers. They suggested that the effect of specialization appeared to modify the search strategy more than the effect of the length of training. When applied to sport, this may suggest that judging or coaching related training is a greater predicator of refined visual search patterns rather than number of years involved in gymnastics.

2.5.2 Sport-related findings

The majority of literature aimed at understanding visual search of sports performers adopts the expert / novice paradigm. The classification of ‘expert’ and ‘novice’ has been a topic of debate for many decades. Despite this, there is no disagreement across researchers as to the necessity of years of task-specific practice to acquire skilled performance (Hodges, Starkes & MacMahon, 2006). Ericsson, Krampe and Tesch-Romer (1993) suggested that difference in individuals skills were closely related to deliberate practice hours and that ‘expert’ performance is as a result of intense practice extended over at least 10 years which has been suggested to equate to 10,000 hours of practice. Despite this, some visual search researchers have adopted the league status, ranking or professional versus amateur classification of the individuals as their measure of expertise (e.g., Abernethy 1990; Abernethy & Russell, 1984, 1987; Abernethy, Neal & Koning, 1994; Allard & Starkes, 1980; Ripoll et al, 1995, Singer et al., 1996. 1998). Furthermore, the visual search literature investigating the difference between expert and novice sports observers visual search (e.g., coaches, judges and teachers) have utilised classifications based on qualification rather than number of years experience (e.g., Bard et al., 1980; Moreno et al., 2002) and therefore there is still debate as to the most effective measure of expertise. In addition to the expertise debate, there have also been inconsistencies with regard to how the indicator of expertise (e.g., visual search) should be measured.

A number of techniques have been used in the literature to assess visual search strategy. The main strategies used include temporal occlusion, spatial occlusion, verbal reports and eye-tracking. Temporal occlusion involves the selective editing of film footage to remove different points in time to give the participant variable extents of information (Williams et al., 1999). Spatial (or event) occlusion involves selectively occluding specific cue sources for the duration of the trial to determine areas of importance within the footage (Williams et al., 1999). Verbal reports have also been used to examine visual behaviour through the use of interviews. Verbal report data have been collected retrospectively (Williams & Burwitz, 1993) and concurrently (Vickers, 1988). Perhaps the most common method of assessing visual search strategy is through the use of eye trackers.

Eye movement recording techniques have also been used to identify information processing operations involved in complex sport situations. The literature to date investigating visual search suggests that the location and duration of fixations are indicative of the perceptual strategy used by the performer (Moreno et al., 2002). Many studies (Moreno et al., 2002; Savelsbergh et al., 2002; Singer et al., 1996; Williams & Elliot, 1999; Williams & Davids, 1998) used the Applied Sciences Laboratory (ASL; Bedford; USA) eye tracker system or the NAC Eye Mark recorder (California; USA; Ripoll, Kerlirzin, Stein & Reine, 1995). Although robust measurement can be gained from these, each study has failed to examine head movements (with the exception of Rodrigues, Vickers & Williams, 2002, who found no differences in eye- head stabilization as a result of skill or accuracy), thus restricting use in dynamic situations. Although this detracts from the ecological validity of such studies the eye tracker systems, particularly the ASL systems appear appropriate for use in sport contexts (Williams et al., 1999).

Eye tracking recorders can identify fixations, saccades and smooth pursuit eye-tracking. Saccadic movements are “conjugate high-speed jumps of the eyes from one gaze location to another” (Moran, Byrne & McGlade, 2002, p.225). Smooth pursuit relates to maintaining “a line of sight on selected targets during the intervals between the saccades” (Moran et al., 2002, p.225). Specifically, in relation to the sport science literature, eye trackers measure visual fixations. A fixation refers to a time period of 120ms or above when a performer is focusing on one part of the display (Williams et al., 1999) calculated within two degrees of accuracy (ASL Eye tracking system instruction manual, 2001). The eye trackers record fixation number, duration, and co-ordinates for location and allows identification of visual search patterns including scan paths.

2.5.2.1 Number of fixations

Ditchburn (1973) found that visual sensitivity declines during saccades, because when the saccade is taking place the eyes move quickly and are therefore not able to foveate on specific areas. Theoretically, the greater the number of fixations, the more saccades the eyes will have to produce. Therefore a search strategy that involves fewer fixations is assumed to be more effective (Williams et al., 1999; Mann et al., 2007) as less time is spent in saccadic eye-movement where individuals are not able to use the information in the display. The proposal that experts produce significantly fewer fixations than novices is supported by Bard and Fleury (1976), Helsen and Pauwels (1992, 1993), Moreno et al. (2002), Ripoll et al. (1995), Savelsbergh et al. (2002), Singer et al. (1996), Vickers (1996a,b) and in a meta-analysis of 42 studies based on perceptual-cognitive expertise by Mann et al. (2007). In addition, a number of studies have found that there were no significant differences between the number of fixations by experts and novices sports performers, however there were non-statistical trends where experts produced fewer fixations than novices. These studies involved tasks such as decision time based on typical basketball offensive game situations (Bard & Fleury, 1976), response to attack and openings in French boxing using a joystick (Ripoll et al., 1995), anticipation, reactions and movements to serve and ground stokes in tennis (Singer et al., 1996), attempting to save simulated soccer penalties using a joystick (Savelsbergh et al., 2002), decision making regarding soccer scenarios (Helsen & Pauwels, 1992, 1993), and free throw performance in basketball (Vickers, 1996a,b). These studies suggest that experts employ more refined search patterns as evidenced by the limited number of fixations.

However, the suggestion that experts employ more efficient visual search patterns than novices has not been supported in all research (Goulet, Bard & Fleury, 1989; Moran et al., 2002; Williams & Davids, 1998; Williams & Elliot, 1999; Williams, Davids, Burwitz & Williams, 1994). These studies have found that expert performers produced more fixations than novices. Williams and colleagues explain discrepancies in findings in terms of the complexity of the display. They suggest that displays that contain more information could be considered as more perceptually complex, for example in football an 11 on 11 situation compared to a one on one situation. Williams et al. (1999) suggest that numbers of fixations for both expert and novices would increase in relation to the perceptual complexity of the display and the cognitive complexity required for the task. Therefore the more information that is present within the display and the more choices a performers has to make, the more fixations they would produce. This has implications regarding the types of visual display that performers see when performing. For example, a coach viewing a single performer would expect to produce fewer fixations than a coach working with a group of six performers due to the relative display complexity. However, these studies required differing levels of cognitive complexity and motor skills demands such as identifying types of serve (Goulet et al., 1989), a virtual walk around a computerised show jumping task (Moran et al., 2002), moving in response to filmed offensive sequences in football (Williams & Davids, 1998), and anticipation of pass destination from filmed soccer sequences (Williams et al., 1994). Therefore the complexity of the task in terms of the display and cognitive demands could be considered as varied.

Indeed, complexity may refer to the task that participants are performing when watching the display (cognitive complexity). For example, an analysis of whether a foul was included or not (i.e., a yes or no response) could be regarded as less cognitively complex than rating a performance out of ten using pre-determined criteria. Additionally, judges in gymnastics only have to watch one person at a time, but each performance will vary in relation to the speeds at which the gymnasts move. Also the elements of the skills they are watching need to be considered in relation to pre-determined criteria (e.g., quality of somersault, round off and flick), which could be considered as complex. Bard and Fleury (1976) concluded that fixation number reflected the complexity of the slide display, however they did not statistically relate the finding of fixation duration to task complexity. Thus the assumption made by Williams et al. (1999) that the number of fixations links to the complexity of the task warrants more research including appropriate statistical analysis to link the number of fixations variable to the complexity of the trial.

2.5.2.2 Fixation duration

Fixation duration is also assumed to be indicative of the perceptual strategy used by the performer to extract meaningful information from the display (Williams et al., 1999). The duration of fixation period would therefore reflect the importance of that part of the display. Singer et al. (1996) found that highly skilled tennis players spent longer times fixating on the knee than beginners and less time fixating on the head and ball. This reflects a difference in selective attention with experts looking to different places for different amounts of time to make their decisions. This may be a reflection of differences in perceived pertinence or knowledge bases between expert and novice performers. Helsen and Pauwels (1992, 1993), Moreno et al. (2002), Ripoll et al. (1995), Savelsbergh et al. (2002), and Vickers (1996 a,b) found that experts produced longer fixation duration than novices, although in the Moreno et al. (2002) these were not statistically significant. Mann et al. (2007) also found that experts produced longer fixation durations than novices in their meta-analysis of perceptual-cognitive expertise. However, Savelsbergh et al. (2002) and Moreno et al. (2002) made no attempt to link fixation duration with important parts of the display. Moreno et al. (2002) presented percentage viewing time separately, thus it is not clear if the longer durations were at the most informative parts of the display. Ripoll et al. (1995) linked fixation duration with the parts of the display involved in French boxing. They found that experts spent more time fixating on the head, and less time fixating on the arm-fist than novices indicating that the head is an informative area for French boxers.

Other studies have found that experts produce shorter fixations than novices (Williams & Davids 1998; Williams et al., 1994). Williams et al. (1994) found that experienced soccer players produced significantly shorter fixation durations than inexperienced players, suggesting that experienced players require less time to produce a coherent representation of the display. This may also be related to the complexity of the display, for example, the greater the number of people within the display may result in more fixations of shorter durations in order to produce coherent decisions. The equivocal findings to date may be a reflection of the diverse sports being investigated within the visual search domain. In addition, Abernethy (1990a), Abernethy and Russell (1987), Moran et al. (2002), Petrakis (1987), and Williams and Elliot (1999) all found no significant differences in fixation duration between experts and novices, suggesting that for some sporting tasks such as badminton and karate fixation duration does not appear to be a limiting factor. Furthermore, the equivocal findings suggest that perhaps the limiting factor in the perceptual performance of the novices is not an inappropriate search strategy but rather an inability to make full use of the information available from fixated display features (Abernethy, 1990b).

2.5.2.3 Fixation location

Fixation location is assumed to reflect the important cues used in decision making as determined by the performer (Williams et al., 1999). The notion that experts look at the most informative parts of the display is more complex to test than fixation location, but has been done using visual search data and spatial occlusion paradigms to explore what information provides the most successful response (see Abernethy & Russell, 1987). It is then the role of the performer through perceptual training to look at the proposed locations (see section 2.6). Williams and Davids (1998) found that the most informative areas of the display would change depending on the situation the performers are in. For example, they found that in a three-on-three football situation, masking information from areas other than the ball or ball passer had a detrimental effect on experienced players suggesting differences in selective attention between experienced and less experienced players. In contrast, in a one on one situation no significant differences were found between experts and novices in performance when occluding such areas as the shoulders and head, suggesting that peripheral information was not as important in a one on one situation.

Although fixation location has been investigated in a number of sports including football (Williams & Davids, 1998), badminton (Abernethy & Russell, 1987) and French boxing (Ripoll et al., 1995), the limited number of participants included in such studies suggests that repetition is required in order to generalise and provide concise locations to which expert performers can look, to provide them with the most informative parts of the display. This may be dependent on the situation the performer faces within a game (Williams & Davids, 1998) and different situations within a game may require the use of different cues. For example, the cues used by expert gymnastics coaches, that allows them to anticipate the outcome of a floor, beam or a-symmetric bars routine may be different for one apparatus compared to another. Therefore investigating visual search patterns across differing situations or skills may allow researchers to combine critical pertinent cue information into training aids, thereby enhancing coach or judge effectiveness.

Conversely, differences between experts and novices have not been supported in all research. Abernethy (1990a) found some systematic differences in the information pick-up of the experts and novices in a film task but the differences were achieved with only relatively minor between-group variations in visual search strategy. In an experiment by Abernethy (1990b), set in the natural field setting, no expert-novice differences in fixation distribution, order, or duration were observed on a comparable prediction task. This provides some support for the conclusion that the limiting factor in the perceptual performance of the novices is not an inappropriate search strategy but rather an inability to make full use of the information extracted from fixated display features (Abernethy, 1990b). With regard to the equivocal findings, it is important to investigate whether visual search patterns do appear to be a limiting factor for decision making in the coaching and judging process.

Although fixation location is said to reflect what are perceived to be the most important areas of the display (Williams et al., 1999) the location may be of more importance at one phase in time than another. This is supported by the location-suppression hypothesis. The location suppression hypothesis states that during the location phase of motor performance, the athlete focuses on the most critical location on the target for about one second before the execution of the skills. The fixation is held at that location until an object enters the athlete's visuomotor workspace during which vision is suppressed in order for the task to be performed successfully (Vickers, 2007). Vickers (1996b) explains this in terms of a basketball free-throw. Therefore Vickers (1996b) states that a long fixation duration is initially required on the hoop. In the second phase movement should be initiated slowly so that the fixation can be maintained. Finally fixation offset should occur early, followed by a suppression of vision (experts either blinked or diverted their gaze to areas other than the hoop, the ball, or their hands during the shooting action) to avoid interference. It is suggested that expert sport performers exhibit a longer quiet eye duration than novices (Mann et al., 2007). Quiet eye is a fixation that is located on a specific location or object in the visuomotor workspace with 3^{o} of visual angle for a minimum of 100ms (Vickers, 2007). Visual search papers to date, including Moreno et al. (2002), Ripoll et al. (1995), Singer et al. (1996), Williams and Davids, (1998) and Williams and Elliot (1999), have made no attempt to suggest where the expert performers were looking at what point in time, and therefore fixation order should be considered in future.

2.5.2.4 Scan paths

Ripoll et al. (1995) and Williams and Elliot (1999) recorded patterns of visual search showing how often the performer's eye gaze switched between the locations at specific time phases. Specifically, scan paths allow the temporal patterns of fixations to be explored. The scan paths highlight differences between experts and novices that may be too sensitive to be picked up through statistical tests, showing some of the more subtle differences between expert and novice visual search patterns. This is because scan paths document the temporal relationships of the fixations without reducing the data into a single mean value. This has many implications for the use of peripheral vision and the identification of visual 'anchors' (Williams et al., 1999) where performers fixate on specific areas in a pre-determined order to allow for optimal perceptual performance.

Goulet et al. (1989) investigated visual search patterns when preparing to return tennis serves and found that both expert and novices were looking at different cues in the preparation, ritual and execution phases. They also found that experts selected valuable information at the preparatory phase and identified more serves correctly than novices. Savelsbergh et al. (2002) also found differences between expert and novice goalkeepers' fixation locations at times leading up to the penalty. This implies that it was not only the cues that were important, but also the time of looking at such cues. Coaches' and judges' scan paths have not been investigated within the gymnastics coaching and judging literature. Therefore the present research aimed to investigate visual search patterns in relation to a time frame, as this may provide more accurate and beneficial practical implications. In conclusion fixation locations are specific to position, time and task within the same sport.

2.5.2.5 Unclassified areas

Interestingly, much of the visual search research (Bard & Fleury, 1976; Ripoll et al., 1995; Savelsbergh et al., 2002; Williams & Davids, 1998) has identified times where performers were not looking at the specified areas of the display. Often the researchers called these areas the 'unclassified' or 'unidentified' areas. Perhaps the most pertinent findings from such research were that experts spent more time, when searching parts of the display at specific times, looking at these areas (Bard & Fleury, 1976; Savelsbergh et al., 2002; Singer et al., 1996). Savelsbergh et al. (2002) also found that novices looked at unclassified areas early on in the movement. Potentially, unclassified areas may provide a part of the display to which performers can 'anchor' their foveal vision close to key locations to maximise their potential to use the periphery, for picking up relevant cues. Williams et al. (1999) explain this in terms of using the periphery to pick up movement as it is more sensitive to this than the fovea.

Alternatively, it has been suggested that the cues are less important than relative movement between areas (Ward, Williams & Bennett, 2002). This is supported by the finding that the unclassified areas are often orientated at intersection of different cues (Ripoll et al., 1995). Therefore the unclassified areas must not be disregarded as irrelevant as they have the potential to be used as 'visual pivots' which allow the performers to actively search based upon the location (Williams & Elliot, 1999).

Williams and Davids (1998) however found that unclassified areas were not used as pivots and that specified cues in the display could be termed pivots from which performers can search other parts of the display. This explanation evolved from the finding that performers look primarily at one part of the display, but occluding this area did not result in a decline in the performance. Thus, logically, performers may be making use of the periphery to gain the most important information. This is supported by Williams and Davids (1998), who found that in 3 on 3 football situations masking peripheral areas had a greater effect on experts, implying that experts use more peripheral vision to anticipate. Alternatively, unclassified areas may arise as a result of the researchers using limited categories to analyse their results. The following research aims to analyse the data with as many categories as necessary to avoid the vague category of unclassified and therefore contribute a more detailed analysis to aid coaches and judges.

2.5.3 Visual search in gymnastics settings

Of primary importance to this thesis is the role of visual search for gymnastics coaches and judges. To date, two studies have been conducted in this area. Moreno et al. (2002) examined the differences in visual search between experienced and inexperienced gymnastics coaches utilising a group based design. This study investigated fixation numbers and durations produced when viewing a gymnastic floor routine consisting of handstands, front handspring and round-off back handsprings. They found that experienced coaches made significantly fewer fixations ($p = .007$) of longer duration (p value not presented) during the gymnastics routine, suggesting that visual search may be a contributing factor in coaching performance. However, caution should be taken when interpreting such results due to the low number of participants in the expert and novice groups ($n = 3$). In relation to judges, Bard et al. (1980) investigated visual fixations of expert (national) and novice (local) judges whilst viewing four routines on the beam. They found that more experienced gymnastic judges, when viewing routines on the balance beam, produced 27% fewer fixations than the less experienced group, indicating perhaps the expert judges concentrated more on environmental aspects that they consider important, while novice judges are less selective (Bard et al., 1980). However, the findings in the Bard et al.

(1980) study were not significantly different, thus only tentative conclusions can be drawn in relation to expert-novice differences.

2.5.4 Summary of Visual Search

In summary, visual search patterns indicate the parts of the display in which performers gain the information needed to carry out the required task. Research to-date indicates a relationship between visual search and a number of variables including anticipation (e.g., Rowe, Horswill, Krnnvall-Parkinson, Poulter & McKenna, 2009), but has yet to form direct links between such variables. The research also seems to be situation specific within the same sport. Therefore research is needed to investigate visual search patterns of coaches and judges in gymnastics, as this has not yet been studied in detail. Also, specific research needs to attempt to link visual search to other variables such as decision making. This will allow more substantial evidence that visual search plays a role in decision making. Additionally, the effects of altering visual search through the use of perceptual training programmes have not been well documented in the literature.

2.6 PERCEPTUAL TRAINING

The perceptual abilities of certain populations can undergo improvement through training (Franks & Miller, 1991; Smyth, 1984). As such perceptual learning refers to the relatively long term changes to the perceptual system that improves its ability to respond to its environment (Goldstone, 1998). However, few studies have examined the perceptual skills of skilled observers in sport settings (Franks, 1993). The neglect of the topic by researchers has hindered the design and implementation of training programmes for teachers and coaches “who, from lack of it, have been forced to train themselves through the random contingencies of day-to-day teaching” (Imwold & Hoffman, 1983, p. 149).

There are a number of assumptions that underpin the perceptual training process. This first is that there are systematic differences between the performance of experts and novices in sport. This would suggest that there is a mechanism or specific mechanisms limiting the performance of novices. Secondly, the assumption from a perceptual training viewpoint is that the differences between experts and novices are linked to perceptual processes. Thirdly, perceptual training relies on the fact that researchers are able to determine what experts are doing throughout the perceptual process (Williams & Ericsson, 2008). In addition, perceptual training assumes that the information gathered from experts can be developed into a coherent training programme (Williams & Ericsson, 2008). Finally, it assumes that novices will be able to utilise the information from experts to their advantage. The research documenting the efficacy of this process is reviewed in this section.

The documented importance of perceptual processes in sport has led to the development of generalised training programs, claiming to improve general abilities such as depth perception, visual acuity, and peripheral vision (e.g., Sports Vision, Revien & Gabor, 1981; Eyerobics, Revien, 1987; Sports Vision, Wilson & Falkel, 2004). However, the benefits of such programs lack empirical confirmation (Hagemann, et al., 2006). In direct contrast, there is empirical evidence that visual processing can be trained in specific sports (Farrow & Abernethy, 2002; Farrow, Chivers, Hardingham & Sachse, 1998; Williams, Ward & Chapman, 2003; Williams, Ward, Knowles & Smeeton, 2002).

Despite findings in some laboratory studies that experts are characterised by less frequent visual search fixations than novices (e.g.,, Abernethy, 2001; Bard & Fleury, 1976; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996) and conceptions that training visual search might not be beneficial in the development of expert performance (Abernethy et al., 1999), the ecological approach to visual perception suggests that it may be effective to increase the extent to which coaches and judges explore for information. Specifically the ecological approach argues that experts are more attuned to searching for affordances (the opportunities for action, Gibson, 1979) within a display and are therefore able to produce a higher level of motor performance. This is supported by studies showing that experts search more frequently than novices (Goulet et al., 1989; Moran et al., 2002; Williams & Davids, 1998; Williams & Elliot, 1999; Williams et al., 1994).

Understanding how best to train perceptual and decision making skills for sport is hampered by a shortage of well-controlled training studies (Abernethy, 1996). The designs of the videos used in perceptual training studies have not been made explicitly clear by the researchers (e.g., Abernethy et al.,1999; Cascerta et al., 2007; Mascarenhas et al.,2005; Williams et al., 2002). However, such interventions usually include a large explicit component in which performers are directed, through visual, verbal, or auditory instruction, to attend to specific visual cues, coupled with repeated exposure to video stimuli, usually depicting a high-level performer (Jackson & Farrow, 2005). However, there has been some debate over the best ways to present the content to the performer. Such debate has led to studies comparing different types of training techniques on performance.

When individuals deliberately use problem-solving strategies such as formulating or testing hypotheses to gain knowledge, the process of learning is considered explicit and is called ‘explicit learning’ (Berry & Dienes, 1993). Explicit processes mediate the conscious interaction of performer and environment (Gentile, 1998). Guided discovery is less directed than explicit instruction, where performers’ attention is guided to general regions and they are left to discover the relationships between cues/movement patterns and behavioural outcomes. Guided learning is less directed than guided discovery because explicit instruction is withheld (Jackson & Farrow, 2005). When individuals accumulate knowledge passively and no conscious analytic strategies are used, the learning process is considered implicit and is called `implicit learning' (Berry & Dienes, 1993). Implicit processes are not consciously available to the performer (Gentile, 1998). Guided discovery and explicit training programmes have been shown to increase the anticipatory ability of tennis players (Williams et al., 2002). However, the impact of explicit and guided discovery based perceptual training programmes on judgment formation has yet to be determined.

Poulter, Jackson, Wann and Berry (2005) examined the efficacy of explicit and implicit learning paradigms during the very early stages of learning the perceptual-motor anticipation task of predicting ball direction from temporally occluded footage of soccer penalty kicks. A significant improvement ($p<0.05$) in horizontal prediction accuracy was observed in the explicit learning group but a similar improvement was evident in a placebo group who watched footage of soccer matches. In addition, only the explicit learning intervention resulted in changes in eye movement behaviour in line with the instructions given to the participants, suggesting that explicit based training videos may be most effective for altering point of gaze based behaviour.

Recent research has shown that interventions based more towards the implicit end of the continuum are effective in aiding decision speed (Smeeton, Williams, Hodges & Ward, 2005) and decision accuracy in decisions of low complexity (Raab, 2003). However, Raab (2003) also found that more explicit based interventions produced more accurate decision making in high-complexity decisions, thus a guided discovery based intervention may be most appropriate for enhancing cognitive performance. Indeed, Smeeton et al. (2005) found that participants who underwent a guided discovery based intervention produced faster decision making under anxiety-provoking conditions. The implication from this research is that explicit based training interventions could be ineffective in anxiety based conditions, thus guided discovery may be more appropriate for judges that feel under pressure when judging competitions, however this has not been investigated.

As previously stated, much of the visual search research (Bard & Fleury, 1976; Ripoll et al., 1995; Savelsbergh et al., 2002; Ward et al., 2002; Williams & Davids, 1998) has identified times where performers did not anchor their vision on specific cues and consequently may have used peripheral vision to analyse the performance (Williams & Davids, 1998). Indeed, it is widely accepted that full knowledge of central gaze behaviour does not provide exhaustive information on which stimuli are actually perceived, because experts may use peripheral stimuli in relation to a focal point of gaze when controlling their behaviour (Williams et al., 1999). Also, it seems that attention can be moved around the visual field without making distinctive eye movement to change point of fixation (Jonides, 1981; Sanders & Houtsman, 1985). Therefore Williams and Davids (1997) highlight the need to combine eye movement registration techniques with parallel measures of information extraction when attempting to understand the perceptual strategies employed by performers.

In the most recent reviews of perceptual training, Mann et al. (2007), Ward et al. (2008) Williams and Grant (1999) and Williams and Ward (2003) suggest that cognitive interventions that develop the knowledge base associated with perceptual skill have more practical utility than clinically based visual skills training programmes. Studies conducted in football (Damron, 1955; Londeree, 1967), baseball (Burroughs, 1984), and tennis (Caserta et al., 2007; Haskins, 1965) have shown that perceptual training can improve decisions made on tactical play scenes in the respective sports. Typically, these studies included the participants identifying the play or play outcome as a result of a brief period viewing play-action slides or video tapes. Although there have been a limited number of field-based studies (Adolphe et al., 1997; Harle & Vickers, 2001), a typical cognitive intervention has included video simulations that replicate the performer's expected view of the action. The film sequences are then presented to the learner either in real time or slow motion along with the instruction to focus attention on the most informative cues. The tapes aim to highlight the relationship between the key information sources and following action requirements and give feedback about the correct response.

This type of approach has been utilised to improve anticipatory performance for soccer penalty kicks (Williams & Burwitz, 1993), tennis serves and passing shots (Abernethy et al., 1999; Singer et al., 1994) and American football (Christina et al., 1990). Abernethy et al. (1999) aimed to examine whether the anticipatory skills of novice racket sport players could be made more analogous to experts through using a combination of video-based and knowledge-based training, using appropriate placebo control groups. The training intervention targeted aspects of perception known to be critical for expert performance in racket sports. Anticipatory skill was assessed pre- and post-training using established laboratory measures in which the speed and accuracy demands were constant for all participants. The results of this experiment provided evidence that anticipatory skill can be enhanced with practice. The group who experienced a combination of perceptual training techniques directed at factors known to limit the anticipatory performance of novices showed significant pre- to post-training improvements in anticipatory skill. The improvements were not seen in either the placebo group (who were given comparable amounts of training time and expectations of benefits from training but a different training regime) or in the control group (who were simply given physical practice).

Williams et al. (2003) aimed to determine whether anticipatory performance for the field hockey penalty flick could be improved following a structured perceptual training programme using video simulation, instruction, and feedback, using a measure of performance transfer from the laboratory to the field setting. The results from the laboratory test indicated that the participants who underwent perceptual training significantly reduced their decision time by 100ms on the post-test compared with the pre-test. They proposed that the difference in decision time reflected a meaningful improvement in anticipatory performance, as a result of a more refined ability to pick up subtle postural cues. However, no changes in response accuracy as a result of training were found, suggesting that participants were only able to maintain levels of accuracy despite initiating their response earlier. In contrast, no significant pre- to post-test differences in performance were evident for participants in the control and placebo groups. They proposed that the improvement in performance in the group undertaking perceptual training was therefore a meaningful training effect as opposed to the result of increased test familiarity or confirmation bias. However, this study did not utilise a retention stage, thus the proposed effect may have deteriorated once the programme had been withdrawn.

Starkes and Lindley (1994) used video and on-court tests to assess pre- to post-test training differences in novice basketball players. A treatment group participated in six 30 minute training sessions involving video simulation, practice, and feedback, whereas a control group completed the pre- and post-tests only. The trained group showed a significant improvement pre to post-test on the film-based anticipation test compared to the control group, whereas neither group improved their performance on the on-court test. The transfer test required participants to make judgments at the end of various play sequences that were realistically acted out on court. In contrast to Williams et al. (2003), the findings suggest that the improvements observed on the post-test were specific to the laboratory setting and perhaps indicates increased test familiarity rather than a meaningful training effect. The ineffective transfer from lab to on court could be explained through the design of the intervention such that an intervention based on alterations within the ventral steam, may be ineffective when the actual action is initiated by the dorsal stream because it separates perception and action (Mann et al., 2007; see section 3.1.2 for a description).

Although these studies highlight the potential of perceptual training programmes, various limitations prevent a comprehensive evaluation of their usefulness. Most studies have failed to use placebo (e.g.,, reading or viewing other instructional material) or control groups (e.g.,, a no-training group or observation of training film without receiving formal instruction) in addition to the experimental group (Williams et al., 2002; Williams et al., 2003). Williams et al. (2003) therefore suggest that improvements in performance observed might therefore be due to conformation bias (the tendency to adapt one's scores to the scores of judging colleagues, Gorman & Farrow, 2009; Scheer, Ansorge & Howard, 1983; Vanden Auweele, Boen, De Geest & Feys, 2004; Wanderer, 1987) or increased familiarity with the test environment rather than any meaningful treatment effect (Christina et al., 1990; Singer et al., 1994).

Additionally, other researchers have aimed to examine the impact of 'decision making training' based on knowledge rather than visual search in sport. Mascarenhas, Collins, Mortimer, and Morris (2005) attempted to train decision making in RFU officials using footage of tackles using verbal report data. The clips of tackles were then interpreted by the number 1 ranked RFU referee, followed by a further re-run of each clip. Mascarenhas et al. (2005) found no significant differences in accuracy of decisions based on their training videos, except in the lower level referees. However, this study had not used a placebo group, raising the possibility that limited benefits were due to the familiarity effect. Such studies should therefore include a placebo group to account for this effect.

The above research focuses mainly on dependent variables such as anticipation, decision making and outcomes score. However, the focus for this thesis is on the effects of perceptual training on visual search and judgment formation. To date, there have only been three studies that have focused on perceptual training in relation to visual search variables in sport.

2.6.1 Perceptual training and visual search adaptations

Adolphe et al. (1997) examined the effects of a six week visual attention training programme on accuracy of nine volleyball players and tracking onset, tracking duration and tracking offset of three volleyball players. The intervention aimed at altering the ventral stream included, amongst other things, video feedback of gaze behaviour. They found that the programme produced significant improvements in tracking onset (with earlier tracking onset), tracking duration (which was longer), and tracking offset (which was later). In addition a three year follow up found that athletes who had received the visual attention training were significantly more accurate than those that had not received training, but no visual measures were taken at this time-point. However, Adolphe et al. (1997) acknowledge the low participant numbers involved in the study and advises caution when interpreting the results.

Harle and Vickers (2001) investigated whether training quiet eye improves accuracy in the basketball free throw. Quiet eye is when the performer fixates or tracks a critical object prior to initiating a specified movement (Vickers & Adolphe, 1997). Harle and Vickers (2001) found that university basketball players who received 1 hour of quiet eye training improved significantly over two seasons of league play, in accuracy of free throw shooting, increased quiet eye duration, and relative shot timing. However, when accuracy was compared, over two seasons, with two teams who had not had quiet eye training, there were no significant differences suggesting limited support for perceptual training of quiet eye duration.

Surprisingly, there has only been one documented study investigating the effects of implicit and explicit training on visual search variables. Poulter et al. (2005) conducted a study investigating performance and visual search behaviour as a functions of instruction condition during the early stages of perceptual motor learning. Poulter et al. (2005) found that an implicit perceptual training programme did not change visual search behaviour (number of fixations and percentage viewing time) of non-sports players ($p>0.05$). However, the explicit training programme produced significant changes in allocation of viewing time from pre to post test consistent with instructions given to the participants.

2.6.2 Limitations of perceptual training literature

One limitation of the perceptual training literature is that previous researchers did not establish a baseline for performance by including a pre-test (Ward et al., 2008). In addition, in relation to the perceptual training and eye-tracking literature, researchers have not determined whether the visual search variables are consistent before manipulating them. For example, Williams et al. (2002) reported that visual search became more variable under high anxiety conditions. However, the consistency of visual search under conditions with no anxiety was not reported, leaving unanswered questions regarding natural variation. Therefore this research programme will address this issue by indentifying the natural variation of the three most commonly investigated visuals search variables (number of fixations, fixation duration and number of areas fixated).

In addition, the perceptual training literature to-date focuses specifically on athletes and performers rather than officials, coaches and judges. This is surprising given that coaches and judges rely entirely on perceptual expertise. Sports performers alternatively also require expert physiology, tactical expertise, and technical expertise in order to be able to perform (Janelle & Hillman, 2003). This research programme will therefore investigate the application of a perceptual training programme on coach and judges populations.

Many of the limitations of the perceptual training studies to-date relate to the methods used to collect data or train the athletes. There have only been three previous studies that have attempted to train visual search within the sports literature. The duration of the period of data that the researchers have collected in order to assess changes in visual search range from the duration of a single fixation (quiet eye) which could be as little as 99.9ms (Adolphe et al., 1997; Harle & Vickers, 2001) to the final one second of data leading up to a penalty kick (Poulter et al., 2005). Such limited time gives only a brief snapshot of the changes that are made in terms of the perceptual strategies and may mask some of the effect that the programme is having. However, given that much research has identified the use of early cues as part of experts' perceptual strategy (Abernethy & Russell, 1987), this limited analysis will not allow changes in the use of early cues to be identified. In support, Ward et al. (2008) suggest that training should be based upon empirical evidence of expert performance and that evidence needs to be temporally specific to have the desired training effect. The present research programme will therefore document changes in visual search throughout an entire performance allowing temporal variations in search to be identified.

Furthermore, poor documentation of the training video design has limited the replication of successful perceptual training programmes. The most recent perceptual training study in sport used a five day training period and reported that participants were instructed about "the cues that provide the most useful information with regards to where a shot will be hit" (Caserta et al., 2007, p. 485). However, Caserta et al. (2007) do not report where they got this information from. The impact of not providing this critical data means that such studies cannot be replicated. Williams et al. (2002) fail to explain how the cues were highlighted in their perceptual training study. Abernethy et al. (1999) utilised formal instruction on biomechanics of shooting, but do not state where this information came from. In addition, Abernethy et al. (1999) also included formal instruction on locating the most important anticipatory cues. However, how they determined the most important anticipatory cues have not been stated in their research. These poorly documented methods prevent researchers from replicating the research and deny the opportunity to compare the best methods of perceptual training. This thesis will address this issue by documenting the exact information that was included in the perceptual training programme and will also demonstrate how the information was presented.

Additionally, the perceptual training programmes documented have varied from one hour of training to six weeks of training, with very little focus on repeated exposure to training. For example, Adolphe et al. (1997) developed a six week on court perceptual training programme. However, only one session was explicitly dedicated to providing visual search information. The other five sessions were practically orientated, but the study states that the practical tasks were designed to facilitate early detection and improved tracking of the ball. Other research has used substantially shorter perceptual training interventions. Both Harle and Vickers (2001) and Poulter et al. (2005) only conducted one perceptual training session and found changes to varying aspects of vision such as quiet eye duration (Harle & Vickers, 2001) and percentage viewing time on 'relevant' areas (Poulter et al., 2005) by athletes. Williams et al. (2002) and Williams et al. (2003) also conducted one perceptual training session between the pre and post tests. A problem with this limited design is that further improvements may have happened had they trained the participants over a longer period and that the full extent of the training has been over looked. This thesis will therefore include a six week perceptual training programme to address these concerns.

Finally, there have been no studies that have investigated a retention effect in relation to eye tracking in the sport-based literature. Researchers have implied that changes made after the perceptual training programme, such as the faster response speed, higher percentage of accurate responses and higher percentage of performance decision making made by the tennis players in post-tests (Caserta et al., 2007) are long term. However, there is no scientific evidence to support this. This research programme will therefore investigate whether there is a retention effect on visual search variables as a result if the perceptual training programme.

2.6.3 Summary of perceptual training

In summary, perceptual training appears to have a positive impact on a number of psychological variables such as anticipation (Hagemann et al., 2006; Starkes & Lindley, 1994; Williams et al., 2003) and decision making (Burroughs, 1984; Damron, 1955; Haskins, 1965; Londeree, 1967). However, the impact of perceptual training on visual search variables has yet to be confirmed. The limited number of relevant studies to date suggests that perceptual training does appear to have benefit in terms of training visual search. However, these studies have been conducted to aid sports players rather than sport observers such as coaches or judges and the training is limited to very short periods of time (e.g., the training of one fixation). Consequently, the impact of perceptual training on the search variables of sports observers needs to be addressed. Furthermore there has been no research investigating the efficacy of such training for gymnastics observers.

2.7 SUMMARY

To summarise, subjective judgments in gymnastics have been largely understudied in relation to cognitive processing. The studies that exist in this area have largely explored visual search patterns (Bard et al., 1980; Moreno et al., 2002) or knowledge structures (Côté et al., 1995 a,b; Franks, 1993; Ste-Marie, 1991, 1996, 1999, 2000, 2003). However, a limited number of studies to-date have combined knowledge and visual search patterns in order to train judgment formation. To develop an effective perceptual training programme, visual search needs to be explored in relation to how consistent it is, and whether expert coaches and judges visual search patterns are different from novices. This would lay the foundations to create perceptual training programmes aimed to alter the visual search patterns of coaches and judges. However, Williams and Davids (1997) highlight the need to combine eye movement registration techniques with parallel measures of information extraction when attempting to understand the perceptual strategies employed by performers and this lends itself to the use of interviews to help elicit such knowledge. This programme of research therefore aims to address these issues, through four related studies.

2.8 PROGRAMME OF RESEARCH

2.8.1 Study 1

The consistency of visual search by gymnastics coaches and judges will be determined using a visual analysis technique. Where the coaches and judges look will be assessed using footage of ten handspring vaults. Consistency will be assessed through Wilcoxon tests with follow up binary logistic regression and coefficient of variation analysis. The information from this chapter will provide information pertinent to aim one of the thesis.

2.8.2 Study 2

The differences between visual search patterns of novice and expert gymnastics coaches and judges will be examined using a visual analysis technique. Differences in fixation number, fixation duration, number of areas fixated, and score data will be assessed using a one way ANOVA. Differences between percentage time fixating on each area will be assessed using Mann Whitney U tests. This study is designed to meet aim two of the research programme and the information gained from the study will be used to inform study three.

2.8.3 Study 3

This study will examine the visual search patterns and knowledge bases of expert gymnastic coaches and judges. Fixation number, fixation duration and fixation location data will be collected for each Individual participant for each vault. Additionally each participant will take part in a semi-structured interview. Subsequently a common occurrence rule (more than 50% of participants for more than 50% of vaults) will be applied to both data sets to draw conclusions. This study is designed to meet aim three of the research project and the information gained from the study will be used to inform perceptual training DVDs to be used as an intervention for study four.

2.8.4 Study 4

This study is designed to examine the effects of perceptual training on visual search patterns. Specifically, changes in fixation number, fixation duration, fixation location and score will be examined for two groups over a 6 week training period, with a further data collection after a four week retention period. This study is designed to meet aim four of the research project and the information gained from the study will be used to examine the impact of the perceptual training DVDs developed from the data in study three.

2.8.4 Study 5

This study is designed to examine the effects of perceptual training on visual search patterns. Specifically, changes in fixation number, fixation duration, fixation location and score will be examined for four individuals over a 6 week training period, with a further data collection after a four week retention period. This study is designed to meet aim four of the research project and the information gained from the study will be used to examine the individual impacts of the perceptual training DVDs developed from the data in study three.

Eye tracking measurement

This chapter will commence with a review of the principles of visual analysis and quantitative analytical methods will be discussed. The methodology used for the eye tracking procedures (chapters four to seven) will be established.

3.1 INTRODUCTION TO VISION

Vision is our primary sensory experience (Kolb & Whishaw, 2004). In sports activities, visual attention to environmental context information is essential (Magill, 2001) and optimal visual performance requires clear and focused ocular media and visual pathway transference to the primary cortex (Loran & MacEwen, 1995). This information is then used in coordination with sensory, motor, perceptual and cognitive skills to produce skilled action. A review of the physiology of the eye can be accessed in Kolb and Whishaw (2004). In addition to the physiology of the eye, the visual pathway is important in the perception process.

The visual pathway involves a complex communications network designed to transmit information gathered by the photoreceptors to the brain, allowing the individual to make sense of the environment (Williams et al., 1999).

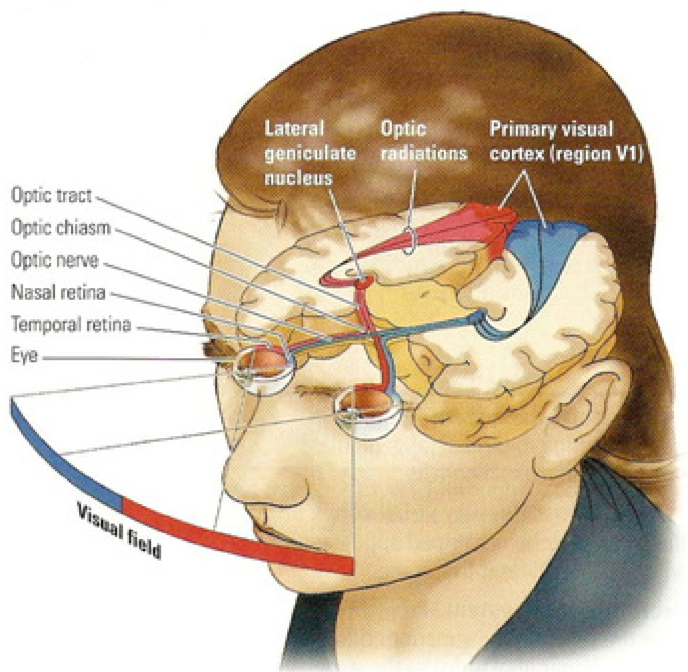

Figure 3.1: The visual pathway (Kolb & Whishaw, 2004). Image reproduced with permission from Worth Publishers, 2008.

Prior to entering the brain, the optic nerves cross creating the optic chiasm, after which half of the axons in each optic nerve cross to enter the contra lateral tract (Kolb & Whishaw, 2004). The optic tract subsequently wraps around the midbrain to get to the lateral geniculate nucleus (LGN), where all the axons must synapse and then enter the occipital lobe (Kolb & Whishaw, 2004)

The visual cortex is divided into the dorsal and ventral streams (Goodale & Milner, 1992). The ventral stream is associated with visual perception and identification of objects (van der Kamp, Fivas, van Doorn & Savelsbergh, 2008). It has strong connections to the temporal lobe (which stores long-term memories), the limbic system (which controls emotions), and the dorsal stream (which deals with object locations and motion). The dorsal stream mediates the required sensorimotor transformations for visually guided actions (van der Kamp et al., 2008).

Transformations carried out in the ventral stream permit the formation of perceptual and cognitive representations which embody the enduring characteristics of objects and their spatial relations with each other (Goodale & Milner, 1992), thus allowing sports performers to recognise for example the size and location of a ball. However, those carried out in the dorsal stream utilise the instantaneous and egocentric features of objects, and mediate the control of goal-directed actions (Goodale, 1993), therefore allowing sports performers to make contact with the ball (action). However, of interest to this thesis is visual perception and decision making, rather than action and, as such, interventions should be based on development of the ventral stream that deal with perception rather than the dorsal stream that deals with action.

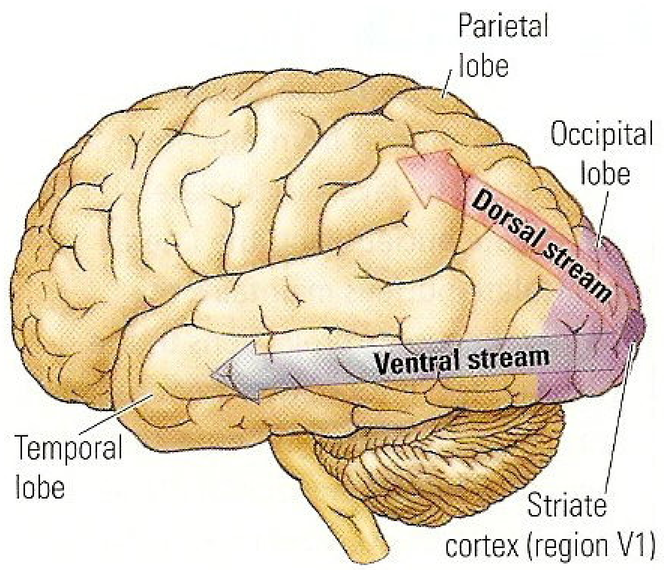

Figure 3.4: Visual streams (Kolb & Whishaw, 2004). Image reproduced with permission from Worth Publishers, 2008.

The two visual system suggest that sports people required to evaluate performance may rely more heavily on the ventral stream as they are required to attach meaning and significance to actions taking place in the display. However, the dorsal root would seem more appropriate to sports participants performing motor skills (van der Kamp et al., 2008; Williams et al., 1999). Once sports people have evaluated the performance, acting upon this information and proposing ways of improving the action may be controlled by the ventral stream. Thus depending upon the task that sports people are required to undertake, different areas of the brain will be employed to a greater or lesser extent. The resultant patterns of vision can be analysed using eye-tracking systems.

3.2 EYE TRACKING

Eye tracking techniques provided psychologists, neurologists, neuroscientists and ophthalmologists with a method of determining what people look at when presented with visual information by bouncing infra-red light off a user's eye and following the reflection (ASL Eye tracking system instruction manual, 2001). For example eye tracking can show us what a football referee looks at prior to and during the committing of a foul (Page, Lafferty & Holder, 2004).

3.2.1 ASL Eye Tracking System (Model 501: ASL; Bedford; USA)

The ASL 501 model operates when the eye is illuminated by the beam from a near infrared source and the optical system focuses an image of the eye onto a solid state video sensor (eye camera). Both the illumination beam and the eye image are reflected from a helmet visor, which is coated to be reflective in the near infrared region and transmissive to visible light. A second solid state camera (scene camera) is focused on the scene being viewed by the participant. The illuminator, optics, and both camera sense heads are helmet-mounted. The eye camera sense head and illuminator are contained in a small head mounted optics module mounted near the participant's forehead. The set up this system can be seen in figure 3.3.

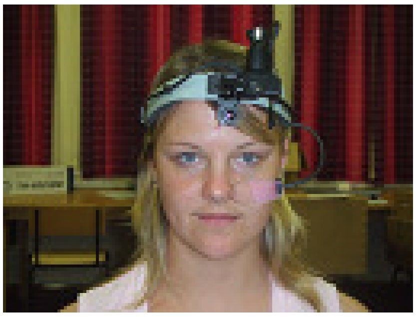

Figure 3.3: ASL 501 Head mounted system.

The model 5000 control unit processes the eye camera signal to extract the elements of interest (pupil and reflection of the light source on the cornea) and computes both pupil diameter and line of gaze. The pupil and corneal reflection outlines and centre cross hairs are displayed on the pupil monitor over the video image of the eye. Eye line of gaze with respect to the helmet is displayed as a set of cross hairs superimposed on the scene camera video image.

The relative positions of the corneal reflex and the pupil are used to compute visual point of gaze with respect to the pre-calibrated nine-point grid projected onto the screen. The degree of accuracy of the ASL 501 is less than one degree (or two degrees in the periphery of the visual field). An eye calibration is performed to verify point of gaze before each participant is tested (see figure 3.4).

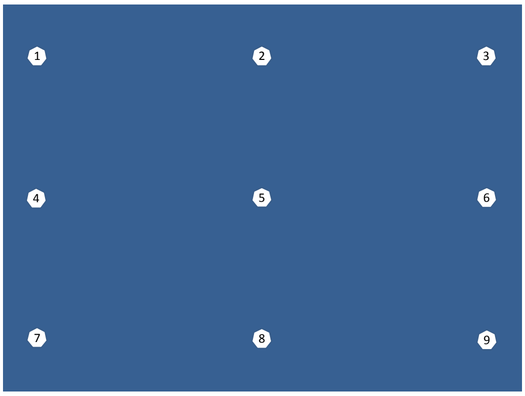

Figure 3.4: Calibration sequence used for each study.

A digital tape of this image is created as a permanent record and used for data analysis. This is analysed on a frame-by-frame basis at 50Hertz (25 frames per second). For the purpose of this thesis, a fixation is defined as when the eye remained on a target for a period ≥120ms. This is in contrast with other studies that define a fixation as when the eye is stationary for a period ≥120ms (e.g., Moran et al., 2002). It is appropriate to re-define fixation for the purpose of this perceptual training thesis, as the studies that have used the stationary eye definition have used static displays so the eye being stationary will relate to one fixation location. Whereas in the current thesis all display were dynamic, thus although the eye may be stationary, the scene may have moved resulting in saccadic eye movements across two of three locations, which is not meaningful for training purposes.

The data collection follows the format of figure 3.5.

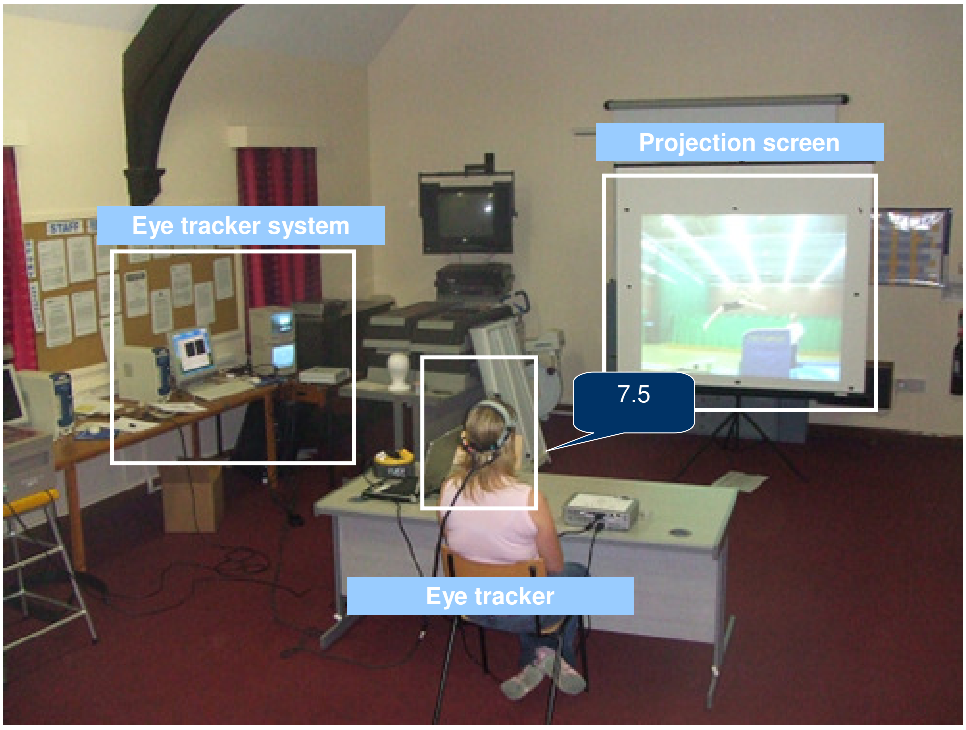

Figure 3.5: Set up of equipment.

Once the data has been collected they are then subject to a frame-by-frame analysis utilising a pre-defined analysis framework.

3.2.2 Analysis framework

Quantitative analysis of visual analysis adopts a biomechanical approach to performance. An 8-point analysis system was adopted in studies one and two of this thesis, figure 3.6 shows the areas of analysis. A more in-depth 13 point analysis system was adopted in studies three and four of this thesis, figure 3.7 shows the areas of analysis. A more detailed analysis was conducted in the latter studies as the aim was to produce a comprehensive perceptual training programme rather than assess differences between perceptual strategies.

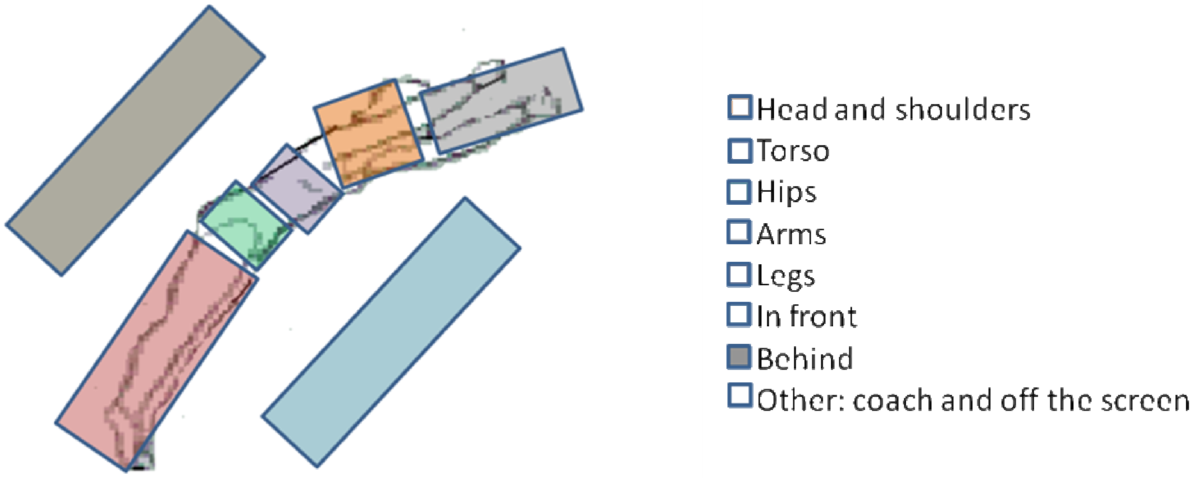

Figure 3.6: The areas of analysis for studies one and two.

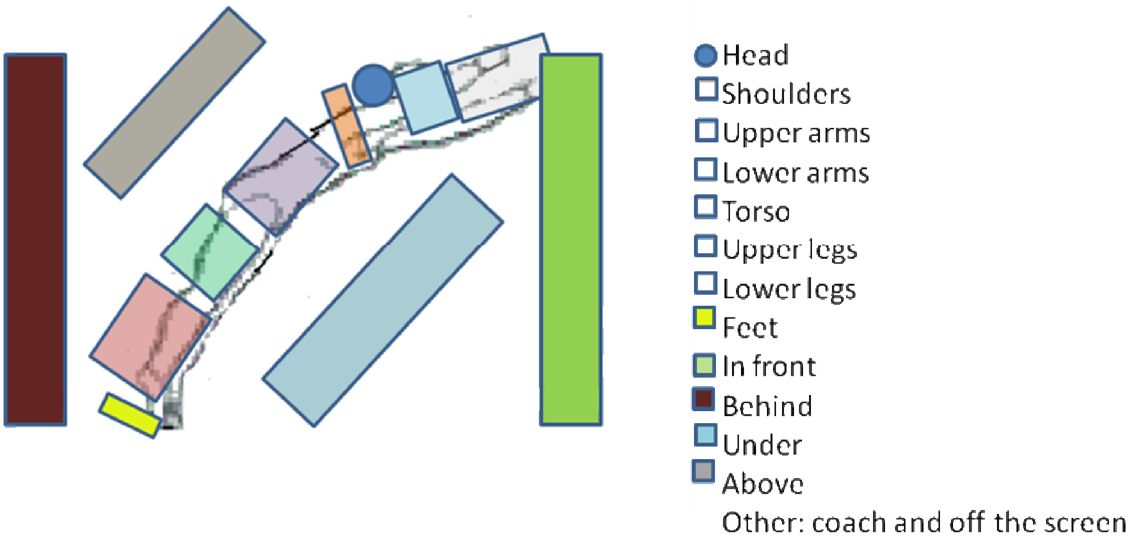

Figure 3.7: The areas of analysis for studies three and four.

The data analysis was completed using a grid with the headings at the top labelling each frame according to the cross hair (see figure 3.8).

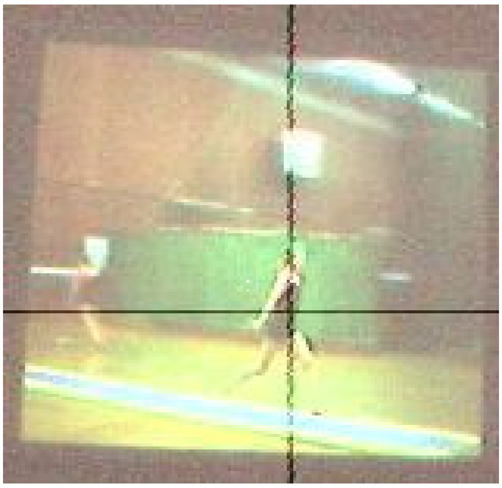

Figure 3.8: Demonstration of crosshair placement

This was the converted into number of fixations, fixation locations, and fixation duration in milliseconds (ms).

Consistency of Coaches' and Judges' Visual Fixations When Viewing a Dynamic Display.

This chapter focuses on the consistency of visual search by gymnastics coaches and judges using a visual analysis technique. Where the coaches and judges look will be assessed using footage of ten handspring vaults. Differences in the data will be assessed through Wilcoxon tests with follow up binary logistic regression and coefficient of variation analysis. The Wilcoxon tests will allow the author to confirm that there are no significant differences between each of the three dependent variables from time-point one to time-point two. The binary logistic regression analyses will be conducted to ensure that the dependent variables are not able to classify scores between time-points one and two, and therefore contribute to any discrepancies in visual search from time-point one and time-point two. Furthermore typical error expressed as coefficient of variation percentage is calculated to understand any variation in the scores. The results from this chapter will provide information pertinent to aim one of the thesis.

Portions of this study have been presented at the European College of Sport Science, Jyvaskyla, Finland, 2007

4.1 INTRODUCTION

Much contemporary research had demonstrated close links between perceptual skill and proficiency in sport (Williams et al., 1999). Perception is defined as the

"acquisition and processing of sensory information in order to see, hear, taste, or feel objects in the world and it also guides an organisms actions with respect to those objects" (Sekuler & Blake, 2002, p. 621).

Perception is therefore a dynamic, serial process, extended over space and time (Shore & Klein, 2001). The discrete, serial nature of visual perception through saccades suggests that memory is required to store and accumulate visual information from objects, as the eyes and attention is oriented from object-to-object within a display (Hollingworth, 2006).

When observing in a stable and predictable environment, it seems likely that object search mechanisms will take advantage of previous knowledge (Chun & Jiang, 1998; Oliva et al., 2004). This knowledge will serve as a source of top-down guidance (Chun & Jiang, 1998; Wolfe, 1994; Wolfe et al., 1989), directing attention to the likely locations of the desired object. In contrast, traditional theories of search such as Treisman's feature integration theory (Treisman & Gelade, 1980) and guided search (Wolfe, 1994) suggest that search of static displays is often guided by bottom up processes (see sections 2.4.1 & 2.4.2 for a review of these models). Subsequent models of search have attempted to describe the processes by which people are able to guide attention in relation to familiar dynamic displays. Chun and Jiang (1998) suggest that "coherent, semantically related visual context can facilitate the detection and identification of component objects and events" (p. 30). This implies that contextual knowledge relating to the display can aid the process of search through the learned associations between the target locations and the context (Chun & Jiang, 1998). Thus, previous fixations held in LTM by coaches and judges should guide future search processes to similar locations, within the scene.

Norman (1968) explains this process of selective attention through the mechanism of pertinent inputs. Therefore consistency in visual search could be as a result of pertinent inputs that are the same each time an observer watches the same performance. Empirical evidence for this does not exist within the sports based literature and as such research examining this process in complex dynamic scenes would aid our understanding of the potential role of contextual information in the guiding of spatial attention within familiar sporting contexts.

A limited number of studies examining the process of altering visual search through the use of contextual knowledge-based perceptual training aids have been documented in the literature. Adolphe et al. (1997), Harle and Vickers (2001) and Poulter et al. (2005) found changes in visual search as a result of perceptual training (see section 2.6.1 for a review of the findings). Despite the limited number of empirical perceptual training studies investigating visual search, these findings suggest that context-specific experience may impact upon visual search perhaps through the mechanisms of contextual knowledge as suggest by contextual cueing (Chun & Jiang, 1998). This suggests that visual search may only be consistent once declarative and contextual knowledge are fully developed, as changes to stored declarative and contextual knowledge may result in changes to visual search via top-down processing.

Despite past research confirming the important contribution of visual search in observation (e.g., Petrakis, 1986, 1987), whether or not observers are consistent in their fixations has not yet been addressed. This is important as understanding the impact of a controlled environment and the consistent knowledge base on visual search may help researchers to understand more about consistent performance evaluation. Such findings will help determine whether a stable knowledge base and constant display results in stable visual search patterns as predicted by Chun and Jiang (1998, 1999, 2003). In addition, if participants are self-consistent across time, then future research can investigate comparisons between expert and novice observers to determine whether visual search is a contributing factor to elite performance.

In summary, empirical research is required to examine the intra-individual differences in the attention of observers. Such a question lends itself to the use of the visual search paradigm where visual fixations are thought to indicate areas where the observers have fixed their attention. Although the aim of this study is not to empirically test a model, consistent fixations may indicate that observers are indeed able to learn associations between the target locations and the context resulting in contextual cueing (Chun & Jiang, 1998). This study therefore aims to examine the consistency of visual fixations of coaches and judges in gymnastics. Based on the top-down theories of information processing visual search should be consistent across two time-points four weeks apart.

4.2 METHOD

4.2.1 Participants

Participants were recruited from Artistic gymnastic clubs within a 25-mile radius of Chester University. Formal letters explaining the nature of the study were sent to all head coaches and interested parties were asked to contact the researcher who then initiated telephone contact and answered any queries. This convenience sampling method led to the recruitment of fifteen participants. Three participants' data were discarded due to data capture errors. The data capture errors were caused by the fact that the participants did not keep their heads perfectly still during the calibration phase, a problem also identified by Nevalainen and Sajaniemi (2004). This was further exacerbated by the long duration needed to perform the calibration process on the ASL 501 eye tracker. Although the duration was not recorded in the present study, Nevalainen and Sajaniemi (2004) found that the average time needed to perform a calibration was 953.5 ±164.4 seconds which was significantly longer than the Tobii 1750 and ASL 504 systems.

All participants provided informed consent prior to participating in the study (appendix 1) having read the participant information sheet (appendix 2). Ethical clearance was provided by the University Ethics board.

Of the twelve participants seven were coaches (two male, five female) with a mean age of 30.8 years and an average of 9.9 years of experience and five both coached and judged artistic gymnastics (one male, four female) with a mean age of 33.8 years and an average of 5.8 years of experience. All participants reported normal or corrected to normal vision.

4.2.2 Design

This study adopted a within groups repeated measure design.

4.2.2.1 Test Film Development

In order to produce an ecologically valid test film a series of handspring vaults were filmed at two gymnastics clubs over a two-week period. This equated to approximately three hours of film and included over 50 vaults. To ensure that the final film would be commensurate with the view of a judge or coach the footage was taken from the sagittal plane with the video camera (Canon NV7001) positioned perpendicular to the vault (figure 4.1). This position allowed the researcher to capture the entire length of the vault and provided a display representative of a judge's view during competition, thus increasing physical fidelity (Lintern, Sheppard, Parker, Yates & Nolan, 1989). Physical fidelity is the extent to which the simulation looks like the performance context (Williams & Grant, 1999) The own-point-of view recording provides minimum distortion of the complexity and dynamics of naturalistic environments (Omodei, McLennan & Whitford, 1998) and allows the context specific information to be captured.

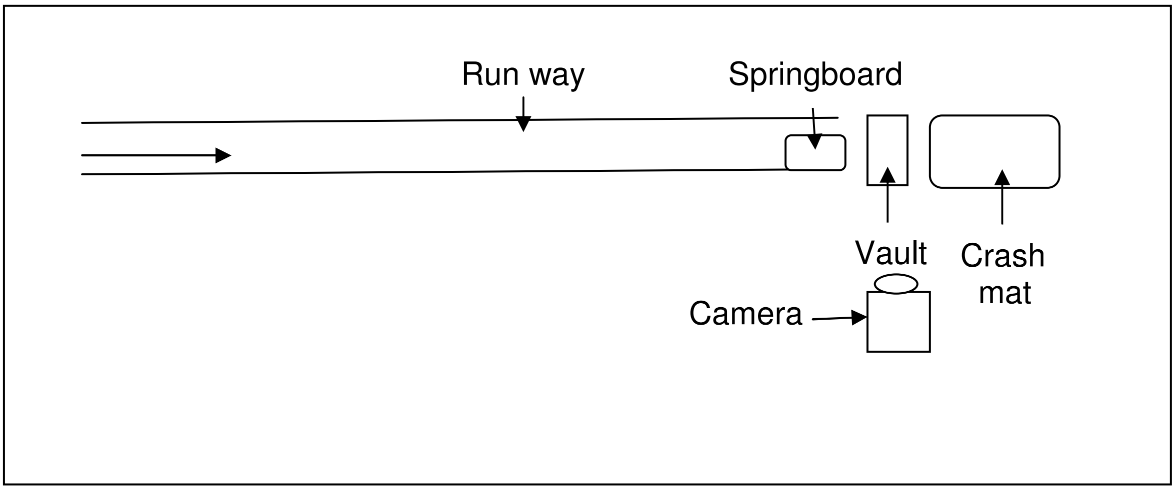

Figure 4.1: Plan view of test film set up

The raw footage was then uploaded onto a computer and the test film developed using iMovie version 3.0.3. A series of 25 single vault clips (approximately 6 seconds duration per vault) were selected from the original footage by an experienced coach as vaults that were representative of what a judge might see in competition. 25 vaults were then picked by the coach as most representative of what a judge might see in competition for later analysis. Each vault clip was then assembled using time frame software to produce a continuous film. Handspring vaults were presented in a randomised order to prevent the occurrence of the order effect. Order effects refer to the tendency to expect a good or bad performance by the athlete as a function of the rank order in which the performance takes place (Ansorge, Scheer, Laub & Howard, 1978; Calkin, 1979; Plessner, 1999; Scheer, 1973; Scheer & Ansorge, 1975, 1980). The gymnasts were not known to the participants to prevent reputation effects (Findlay & Ste-Marie, 2004). To provide time for the participants to feed back their score and to ensure that participants were briefed as to when the next vault commenced, a five second count down segment was inserted prior to each vault.

4.2.2.2 Collection of Visual Search Data

To ensure ecological task validity the film was projected on to a large screen (5ft by 6ft) and participants were seated three metres away thus replicating a real life image size when viewing the film (figure 3.7). To capture visual search data the Applied Science Laboratories (ASL) head mounted eye tracker system (ASL 501) was used. This system measures the eye line of gaze using co-ordinates generated from the head mounted camera (figure 3.5). The unit calculates measured displacements between the left pupil and corneal reflex, and the position of the eye in the head to compute the visual point of gaze with respect to the pre-calibrated nine-point grid (figure 3.6). This information was imposed onto the monitoring unit in the form of a hairline cross and stored using a video camera (Canon NV7001) at 50 Hertz.

4.2.3 Procedure

Participants were tested individually at two different time-points either at the University Motor Skills Laboratory or at specific gymnastics clubs. One week prior to testing each participant was sent an information sheet (appendix 2) and a copy of the previously developed scoring system (appendix 3). Each participant was asked to spend 10 minutes familiarising him or herself with this prior to arrival.

Upon arrival at the venue, the nature of the study and the method of data collection were explained to each participant. To reduce researcher bias, and increase consistency of the environment from time-point one to time-point two, the study was explained using a pre-designed prompt sheet to ensure each participant received the same information and instructions. This standardised procedure aimed to control for psychological fidelity (Lintern et al., 1989). Psychological fidelity is the degree to which the simulation replicates the psychological factors (i.e.,, stress, fear) experienced in the real-world environment (Patrick, 2003). Participants were informed that they would be watching and subsequently judging, using the previously supplied criteria, a series of handspring vaults presented in a randomised order. When all questions had been answered participants gave informed consent both verbally and in writing (appendix 1). Once consent had been gained each participant completed the remainder of the form relating to coaching and judging experience, years within the sport, and roles (appendix 1).

Participants were then seated and the ASL 501 eye tracker was fitted using the head mounted system. Prior to commencement of the test film participants were given a laminated card of the scoring system and guidelines that they could refer to at any time during the testing. This was to ensure that participants could systematically formulate a score rather than relying upon their ability to recall the judging criteria. The participants were also reminded that they were to view each vault and assign a score out of 10 to the action. They were also informed that there was time between each vault for them to verbalise the score. The assigned score was noted on a results sheet by the researcher. Once it was clear that all instructions had been understood testing commenced. A nine point calibration was performed before each participant started (figure 3.6). During testing the judges and coaches were not given information regarding the nature of the performers to avoid any expectation bias (Ansorge et al., 1978). No feedback was given regarding their judging of each vault to reduce the occurrence of the Hawthorne effect i.e., where participants change their behaviour because attention is being paid to them (Thomas, Nelson & Silverman, 2005). This procedure also reduced the occurrence of the conformity effect which refers to the tendency to adapt one's scores to the scores of judging colleagues (Boen, Vanden-Auweele, Claes, Feys & De Cuyper; 2006; Scheer et al., 1983; Vanden Auweele et al., 2004; Wanderer, 1987). Upon completion of data gathering participants were asked questions that focused upon how they felt about the testing protocol and comfort with the eye tracking headgear. No discussion took place regarding the vaults and their scoring performances to reduce biasing at test point two.

Approximately four weeks later participants reported to the same location and repeated the task. This allowed for comparison of visual search over time. The exact testing protocol described above was followed. However, the vaults were presented in a different order in order to disguise the ten analysed vaults.

4.2.4 Data Analysis

4.2.4.1 Raw Data Generation

The cross-hair visual data film was loaded onto an Apple eMac computer and frame-by-frame analysis (50Hz) conducted using Gamebreaker software (Titus Software). This allowed the researcher to record gaze location by frame for each participant by trial (see section 3.2.2 for review of procedure). Recorded visual search data included a fixation analysis for 10 selected vaults. For the purpose of this study a fixation was defined as when the eye remained on a target for a period equal to or greater than 120ms or six film frames, in conjunction with the work of Williams et al. (1999).

The raw visual search data were reduced into number of fixations, fixation duration and number of areas fixated.

4.2.4.2 Statistical Analysis

Three statistical analyses were used to determine the consistency of the visual search data. A triangulation approach was adopted to ensure that the analyses were consistent with the perceptual training literature which primarily adopts a ‘no significant difference approach’ to infer consistency and the biomechanics and physiology literature which primarily adopts a ‘coefficient of variation’ approach to infer consistency. Both Bland and Altman (1986) and Hopkins (2000a) argue against using tests of difference when assessing consistency in data. However, this has not been adopted by other sports psychology researchers when assessing changes in search and therefore it was necessary to include both tests of difference and coefficient of variation tests.

To determine if differences exist in the three visual search variables at time-points one and two, three Wilcoxon tests were used. Non parametric tests were used because the small sample size (n=12) did not allow tests for normal distribution to be carried out (Siegel & Castellan, 1988, p.35). The Wilcoxon tests were suitable tests of difference because the same participants were measured on two occasions (repeated measures) (Pallant, 2005).

In addition, binary logistic regressions (Field, 2005) were used to examine whether the number of fixations, fixation duration and number of areas fixated were able to predict whether the scores belonged to time-point one or time-point two. Three binary logistic regression models were produced, due to the limited participant numbers, in line with Field (2005) who suggests that 12 participants per predictor could be considered appropriate. Binary logistic regression is typically used with an outcome variable that is a categorical dichotomy (Field, 2005). However, the outcome variable in the current study is based on repeated measure time-points and this therefore violates the assumption of unrelated data. Based on this violation, the alpha value was set at 0.01 supported by the guidelines of Stevens (1996). If the dependent variables do not predict time-point membership, then the regression is not able to classify between time-points one and two and as such, the outcome variables could be considered as similar.

In order to consider the meaning of observed differences in visual search variables the natural variation of visual search must be known. Within the sports science literature there has been extensive debate regarding which methods of analysis best describes the reliability of measurements taken on two separate test occasions (test-retest design). However, there have been no published studies that have examined the natural variation of visual search.

In *The Lancet* in 1986, Bland and Altman published a critique of previous attempts to represent reliability, and suggested the ‘limits of agreement’. The limits of agreement effectively described a 95% confidence interval within which the true measurements would be expected to reside. However, Hopkins (2000a) discussed problems within the calculation of the limits of agreement such as whether the t value should be used with small samples or whether the z score (1.96) should be used regardless of sample size (Hopkins 2000b). Hopkins (2000a) also provided convincing arguments against the use of 95% confidence intervals and suggested that “95% is too stringent for a decision limit” (p.4). As an alternative term ‘typical error’ was introduced. Within typical error, variables that deviate from normal distribution must also be log-transformed for the calculation of typical error. However, unlike for the limits of agreement, Hopkins (2000b) describes how interpretation can be simplified by expressing the typical error as a percentage (coefficient of variation expressed at CV). This makes the ‘typical error’ more readily comparable between studies.

Typical error was therefore utilised in this study. Prior to the calculation of any reliability statistics the three visual search variables (number of fixations, fixation duration, and number of areas fixated) were examined to determine the presence of heteroscedasticity. The typical error was calculated using the spreadsheet developed by Hopkins (2000b), and expressed as a percentage (coefficient of variation). See appendix 4 for the calculations.

With the typical error expressed as a CV, the range within which the actual measurement may lie can be easily obtained. If for example if the coefficient of variation for fixation duration was 6.7 and the mean fixation duration between the test and retest was 132.8 ms, the actual fixation duration may vary between 132.8/1.067 to 132.8*1.067 (124.46ms to 141.70ms). Hopkins (2000a) recommends that the expression of the dependent variables range should use */÷1.067, rather than ±0.067 when the coefficient of variation exceeds 5% as it more closely represent the variation in the data.

4.3 RESULTS

The results for the differences in expert and novices visual search patterns, classification ability of the dependent variables and within-participant variation are presented below.

4.3.1 Differences in visual search patterns.

Wilcoxon tests were conducted to examine whether there were any significant differences in the three dependent variables (number of fixations, fixation duration, and number of areas fixated) between the two time-points. The Wilcoxon tests showed that there were no significant difference between the median number of fixations ($Z=-0.59$, $p=0.55$), the fixation duration ($Z=-1.33$, $p=0.18$), or the number of areas fixated between time-points one and two ($Z=-0.54$, $p=0.59$) (see appendix 5). These results suggest that despite any idiosyncratic changes in visual search, as a whole the group did not produce any significant changes in the three dependent variables from time-point one to time-point two. The supporting descriptive statistics are presented in Table 4.1.

Table 4.1: Descriptive statistics for visual fixations at time-points one and two.

	Number of fixations			Duration (ms)			Number of areas fixated		
	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD
Time point 1	3.65	3.89	0.99	172.00	170.20	10.80	2.56	2.54	0.39
Time point 2	3.70	3.83	0.75	166.80	165.60	12.20	2.58	2.54	0.31

4.3.2 Classification ability of the dependent variables

Binary logistic regression analyses were conducted to examine whether the dependent variables were able to distinguish between time-points one and two, and therefore contribute to any discrepancies in visual search from time-point one and two. Specifically, binary logistic regression analyses were conducted to examine whether adding each dependent variable separately to the null model (which includes the independent variable only – time-point), produces a model that is a better predictor of membership to time-point one or two. If for example 'number of fixations' is not able to distinguish between time-points one and two, it is not considered as a contributor to any discrepancies in visual search from time-points one and two. The regression models outputs are presented in Table 4.2.

Table 4.2: Binary logistic regression output

Model	β	SE	Wald	sig	Exb (β)	Lower CI	Upper CI
Number of fixations[a]	-0.41	0.96	0.18	n.s (0.67)	0.67	0.10	4.41
Fixation duration[b]	-0.74	0.76	0.96	n.s (0.32)	0.48	0.11	2.10
Number of areas[c]	-0.02	1.20	0.00	n.s (0.99)	0.99	0.09	10.39

[a] χ^2 (1), 0.18, p = 0.67
[b] χ^2 (1), 1.01, p = 0.32
[c] χ^2 (1),<0.01, p = 0.99

The binary logistic regression analyses show that adding the three dependent variables separately to the null model does not produce models that better predict membership to time-point one or two. Number of fixations (χ^2=0.18, p= 0.67), fixation duration (χ^2=1.01, p=0.32) and number of areas fixated (χ^2=<0.01, p=0.99) were not able to distinguish scores between time-points one and two, they are therefore not considered as contributors to any discrepancies in visual search from time one and time-point two.

The binary logistic regression analyses combined with the Wilcoxon analyses suggests that the three dependent variables are not significant contributors to any discrepancies in visual search from time-point one and time-point two and in addition they do not significantly differ from time-point one to time-point two.

4.3.3 Within-participant variation

The CV for number of fixation was 9.7% and the mean number of fixations between time-points one and two was 3.9, therefore to account for natural variation the actual number of fixations may vary between 3.9/1.097 to 3.9*1.097 (3.56 to 4.28 fixations).

The CV for fixation duration was 5.7% and the mean fixation duration between time-points one and two was 157.7 ms, therefore to account for natural variation the actual fixation duration may vary between 157.7/1.057 to 157.7*1.057 (149.20ms to 166.69ms).

The CV for number of areas fixated was 14.2% and the mean number of areas fixated between time-points one and two was 2.4 areas, therefore to account for natural variation the actual number of areas fixated may vary between 2.4/1.142 to 2.4*1.142 (2.10 to 2.74 areas).

4.4 DISCUSSION

Consistency of visual search has previously been overlooked in the sports science literature. With reference to this, many of the findings within the field of visual search in sport have not calculated a baseline CV and therefore natural variation may account for the changes in visual search, when factors such as anxiety (Williams & Elliot, 1999) and training (Adolphe et al., 1997; Harle & Vickers, 2001) are manipulated. This study aimed to address this limitation of previous literature by examining the consistency of visual search when observing performance under similar conditions.

The results of this study suggest that there were no significant differences in number of fixations from time-point one to time-point two. In addition, the binary logistic regression analyses shows that number of fixations did not help predict whether the scores were from time-points one and two. There was also only 9.7% variation in the number of fixations between the time-points based on the CV. The Wilcoxon, binary logistic regression, and typical error expressed as CV data suggest that when aspects of the environment are controlled, and the observers have no previous information regarding the gymnasts, they will produce a similar number of fixations each time they view the same vault, within a defined range.

There were also no significant differences in fixation duration from time-point one to two. Furthermore, the binary logistic regression analyses shows that fixation duration did not help predict whether the durations were from time-points one and two. There was also only 5.7% variation in fixation duration between the time-points based on the coefficient of variation. Fixation duration is thought to represent the perceived importance of specific areas of the display (Williams et al., 1999). The consistency in fixation duration data suggests that performers view areas of equal importance each time they observe a performance. This would suggest that coaches and judges have cognitive maps that guide their attention to cues for pre-defined lengths of time.

In addition, there were no significant differences in number of areas fixated from time-point one to time-point two. Furthermore, the binary logistic regression analysis shows that number of areas fixated did not help predict whether the scores were from time-points one and two. There was also only 14.2% variation in fixation duration between the time-points based on the coefficient of variation. The number of areas fixated does not allow inference regarding the perceived relevant areas of the display however, the consistent number of areas fixated suggests that observers view a similar number of areas as important each time they view the display.

The consistent visual search findings support the theories of bottom up processing as the scene was identical each time the observers watched the performance and the resultant eye tracking patterns were similar. However, given the dynamic nature of the display such results may be best explained through theories of top down processing. The consistent visual search would suggest that the mechanisms that are driving the search are consistent over time. The mechanisms, whether they are indicators of pertinence (Norman, 1968) or learned associations between the target and the context (Chun & Jiang, 1998), would theoretically be stored in LTM. The LTM would then guide spatial attention towards what are perceived as relevant inputs, and although not directly tested, the consistent visual search would imply that this does happen across a period of four weeks. This finding would be expected given that the observers did not undertake any formal training in the periods between the time-points and the environment and instructional set were the same, thus knowledge base should have remained consistent given the stable nature of the LTM (Schmidt & Wrisberg, 2000). Therefore from a top-down processing viewpoint, the consistent knowledge stored in the LTM led to consistent visual search when other factors were controlled.

The implication of the consistent visual search findings is that without training, visual search may remain unaltered. This may have a detrimental effect on the development of decision making since Bard et al. (1980) and Moreno et al. (2002) found differences in fixations between expert and novice, judges and coaches in gymnastics. In addition, problems may arise if lower level observers (e.g., club judges) consistently fixate on non-informative areas of the display each time they watch a performance. This is because the visual search pattern may remain unaltered until they develop their decision making, slowing down the development process. Future research should therefore conduct a comparison between experts and novice’s attentional processes which would allow researchers to understand the systematic differences between and mechanisms underlying experts’ and novices’ judgment formation. This could indirectly help researchers understand the role of potential differences in knowledge in the guidance of visual search towards relevant areas in the environment.

A Comparison of Expert and Novice Judges' and Coaches' Visual Search When Analysing the Handspring Vault.

This chapter reports the findings of a study designed to examine differences between visual search patterns of novice and expert coaches and judges. Differences will be assessed using a one–way ANOVA for the parametric visual search data and a Mann Whitney U test for the non-parametric percentage time fixating data. This study is designed to meet aim two of the research programme and the information gained from the study will be used to inform study three.

The manuscript for this study is under development for submission to Research Quarterly for Exercise and Sport

5.1 INTRODUCTION

The cognitive processes and visual search patterns that differentiate experts and novices are of great interest to researchers (e.g., Abernethy, 1988, 1990a; Singer et al., 1994, 1996; Williams et al., 1994). Abernethy, Neal and Koning (1994) suggest that “knowing the essential attributes that distinguish experts from novices provides a principled basis for determining what types of practice are most likely to be beneficial for enhancing the development of expertise” (p.185). Once established, knowledge generated from expertise research can be of immediate relevance to sport and exercise scientists, coaches, judges and practitioners involved in the training, testing and identification of potential elite performers.

A sports observer often has to make an immediate selection of relevant cues among many available pieces of information from the environment, while discarding the irrelevant cues (Bard et al., 1980). As such, “visual search appears to be an essential determinant of information processing leading to error detection and accordingly to a decision” (Bard et al., 1980, p.268). The literature on visual search suggests that the number, location and duration of fixations are indicative of the perceptual strategy used by the individual (Moreno et al., 2002). Interestingly, Williams et al. (1999) propose that visual search patterns and cognitive processes differentiate between experts and novices in their ability to detect and use salient information. This study will focus on expert and novice gymnastics coaches and judges visual search patterns with specific reference to fixation number, fixation duration, and fixation location. Differences in visual search between experts and novices through fixation number, fixation duration, and fixation location have been found in a number of empirical studies (see sections 2.5.2.1 to 2.5.2.3 for a review). However, differences between experts and novices have not been supported in all research (see sections 2.5.2.1 to 2.5.2.3 for a review).

Despite the wealth of research investigating visual search by performers in sport, very little research has been conducted into the visual search patterns of sport observers, and as such coaches and judges remain an understudied population (Ste-Marie, 2003). Instead of precise movement control, the key role of coaches and judges is to produce an accurate decision based upon performance analysis. The paucity of research investigating the effects of expertise on visual search variables for subjective decision making is surprising given the controversy surrounding the judging of sporting performances. The only published studies investigating expertise of gymnastics coaches and judges in relation to visual search variables are Moreno et al. (2002) and Bard et al. (1980) who found some differences between the number of fixations, fixation duration, and fixation locations of expert and novice coaches and judges (see section 2.5.3 for a review of the findings).

With regard to the equivocal findings regarding experts' and novices' fixation number, fixation duration and fixation location (see sections 2.2.2.1, 2.5.2.2 & 2.5.2.3) it is important to investigate whether visual search patterns do appear to contribute to decision making. Specifically this study aims to understand the differences between expert and novices coaches and judges visual search during the handspring vault.

5.1.1 Hypotheses

1. Experts will produce significantly less fixations than novices per vault.
2. Experts will produce significantly longer fixation durations per vault.
3. Experts will fixate on fewer locations per vault.
4. Experts and novices will fixate on different areas for different percentage times throughout the handspring vault.
5. Experts will produce less random scan paths.
6. There will be a significant difference in the experts and novices outcome judgments.

5.2 METHOD

5.2.1 Participants

Gymnastic coaches and judges were recruited from British Gymnastics. The inclusion criteria were that they were qualified to women's artistic assistant club coach and / or club judge level for the novice level participants and women's artistic high performance coach and / or national judge level for the expert level participants. This convenience sampling method led to the recruitment of twenty three participants. Three participants' data were discarded due to data capture errors (see section 4.2.1 for an explanation of the data capture errors). All participants provided informed consent prior to initiating the study (appendix 1) having read the information sheet (appendix 6). Ethical clearance was provided by the University Ethics board.

Of the twenty participants twelve were novice level artistic gymnastics coaches and / or judges (three male, nine female) with a mean age of 32.3 years and an average of 7.9 years of experience. The remaining eight participants were expert artistic gymnastics coaches and / or judges (six male, two female) with a mean age of 52.0 years and an average of 13.6 years of experience. All participants reported normal or corrected to normal vision.

5.2.2 Test film – eye tracking

The test film was created from footage collected at two gymnastics clubs' training sessions, filmed from a position representing where a judge would be sat in competition. This own-point-of view recording provides minimum distortion of the complexity and dynamics of naturalistic environments (Omodei et al., 1998) and therefore maximises physical fidelity (Lintern et al., 1989). Eleven videotaped gymnastic vaults were used in the study. One of the 11 was used to familiarise participants with the procedure. All vaults were handsprings, representing what a lower level judge might see in competition.

5.2.3 Procedure

Participants were tested individually either at a Motor Skills Laboratory or at specific gymnastics clubs. One week prior to testing each participant was sent an information sheet (appendix 6) and a copy of the previously developed scoring system (appendix 3). Participants were asked to familiarise themselves with this.

Upon arrival at the venue, the nature of the study and the methods of data collection were explained to each participant. To reduce researcher bias the study was explained using a pre-designed prompt sheet to ensure each participant received the same information and instructions. Participants were informed that initially they would be watching and subsequently judging, using the previously supplied criteria, a series of handspring vaults presented in a randomised order. The gymnasts were not known to the participants to prevent reputation effects (Findlay & Ste-Marie, 2004). When all questions had been answered participants gave informed consent both verbally and in writing (appendix 1). Once consent had been gained each participant completed questions relating to coaching and judging experience, years within the sport and roles (appendix 1).

Participants were then seated and the ASL 501 eye tracker fitted. Prior to commencement of the test film participants were given a laminated card of the scoring system and guidelines (appendix 3), and reminded that they were to view each vault and assign a score out of 10 to the action using the criteria when necessary. The availability of the marking criteria at any time aimed to avoid the issues that novice judges have when trying to recall information about symbol code and criteria (Ste-Marie, 1999). They were also informed that there was time between each vault to verbalise the scores. The assigned score was noted on a results sheet by the researcher. Once it was clear that all instructions had been understood testing commenced. A nine point calibration was performed before each participant started (figure 3.6). During testing the judges and coaches were not given information regarding the nature of the performers to avoid any expectation bias (Ansorge et al., 1978). No feedback was given regarding their judging of each vault to reduce the occurrence of the Hawthorne effect (Thomas et al., 2005) and the conformity effect (Boen et al., 2006; Scheer et al., 1983; Vanden Auweele et al., 2004; Wanderer, 1987). Upon completion of data gathering each participant was debriefed during which questions focused upon how they felt about the testing protocol and comfort with the eye tracking headgear. No discussion took place regarding the vaults and their scoring performances.

5.2.4 Data Analysis

5.2.4.1 Raw Data Generation

The cross-hair visual data film was loaded onto an Apple eMac computer and frame-by-frame analysis (50Hz) conducted using Gamebreaker software (Titus Software). This allowed recording of gaze location by frame for each participant by trial (see section 3.2.2 for review of procedure). Recorded visual search data included a fixation analysis. For the purpose of this study a fixation was defined as when the eye remained on a target for a period equal to or greater than 120ms consistent with Williams et al. (1999).

The raw visual search data for ten vaults were reduced into number of fixations, fixation duration and number of areas fixated. The data were based on an eight point analysis of the display. The eight potential fixation locations included head, torso, hips, arms, legs, in front, behind and other (figure 3.6). An eight point analysis was chosen as it furthered the limited four point analysis of the display and provided more detail than Bard et al. (1980). The in front and behind categories were included because Bard and Fleury (1976), Ripoll et al. (1995), Savelsbergh et al. (2002) and Williams and David’s (1998) found that sport performers fixated on areas other than the specified cues within the display.

5.2.4.2 Statistical analysis

A one-way AVOVA was used to analyse expert/novice differences between the dependent variables' data because five of the eight variables showed normal distribution based on the Kolmogorov-Smirnov statistic ($p>0.05$; see appendix 7). Partial eta squared (η^2) effect sizes were also computed. In line with the recommendations of Clark-Carter (1997), effect sizes of between .001 and .058 were classified as small, effect sizes of between .059 and .137 classified as medium, and effect sizes over .138 were classified as large. A Mann-Whitney U test was used to analyse expert / novice differences in percentage time spent fixating on each of the eight areas because only nine of the sixteen variables showed normal distribution based on the Kolmogorov-Smirnov statistic ($p>0.05$) (see appendix 7).

Scan path analyses were conducted to show the sequencing of fixations (Moran et al., 2002; Ripoll et al., 1995). The percentage time fixating on the eight areas is represented by and directly proportional to the size of the circles. The larger the size of the circle represents a greater amount of time fixating on that area. The sequencing of the fixations is represented by and directly proportional to the width of the arrows. The wider the arrow the more time the participants switched fixations between the areas. An arrow was placed above each of the specific body areas if participants fixated on that body area and then produced a saccadic eye movement which then fixated back on the body area. For example, if a participant fixated on the gymnast's torso and then produced a saccadic eye movement that then fixated back on the torso again and arrow was placed above the torso.

5.3 RESULTS

The differences between fixation number, fixation duration, number of areas fixated and scores, percentage time fixating on the eight areas and scan paths are presented below.

5.3.1 Differences between fixation number, fixation duration, number of areas fixated and scores.

The descriptive statistics relating to differences in visual search data between the experts' and novices' are shown in Table 5.1.

Table 5.1: Descriptive statistics for expert and novice fixation and score data

	Novice		Expert	
	Mean	Std Deviation	Mean	Std Deviation
Number of fixations	3.89	0.99	6.65	0.87
Fixation duration (ms)	170.40	10.80	200.60	23.20
Number of areas fixated	3.13	0.54	2.64	0.41
Outcome judgments (scores)	6.81	0.69	7.12	0.70

A one-way ANOVA showed a significant difference in visual search between the experts and novices (F (4,15) =9.74, p<0.05, effect size η^2 = .72). There were significant differences in number of fixation (F (1,19) =40.28, p<0.05, effect size η^2 = .69), fixation duration (F (1,19) =21.38, p<0.05, effect size η^2 = .54) and number of areas fixated (F (1,19) =11.14, p<0.05, effect size η^2 = .38). Specifically, the experts produced more fixations (mean diff = 2.76), for longer durations (mean diff = 30.2ms), to less areas (mean diff = 0.49). There were no significant differences in the outcome judgments produced by experts and novices (F (1,19) = 0.95, p=0.34, effect size η^2 = .05).

5.3.2 Percentage time fixating on the eight areas

The mean percentage time spent fixating on the eight defined areas of the display for experts and novices are presented in Table 5.2.

Table 5.2. Mean percentage time and standard deviation of time spent fixating on the eight defined areas of the display for experts and novices.

	Novice		Expert	
Area	Mean	SD	Mean	SD
head and shoulder	43.97	25.76	58.21	11.97
torso	6.85	13.35	13.84	3.94
hips	14.61	13.26	10.03	6.91
legs	3.03	2.04	2.23	4.26
arms	5.39	6.54	0.56	0.61
front	6.07	4.86	12.55	33.72
behind	4.39	6.95	2.58	2.76

Table 5.2 shows similar mean percentage times fixating on each of the seven areas between the expert and novice data. The standard deviations are quite high for both the experts (range 0.61 to 33.72) and novices (range 2.04 to 25.76).

A Mann-Whitney U test showed no significant differences in the time spent fixating on each of the seven areas (See Table 5.3).

Table 5.3: Mann-Whitney U data set comparing the eight potential fixation locations

		Novice	Expert
Head	M	8.75	13.13
	U	27	
Torso	M	12.08	8.13
	U	29	
Hips	M	9.5	12
	U	36	
Legs	M	9.08	12.63
	U	31	
Arms	M	12.5	7.5
	U	24	
Front	M	10.38	10.69
	U	46.5	
Behind	M	10.46	10.56
	U	47.5	

M= Mean Rank

U = Mann-Whitney U score

5.3.3 Scan paths

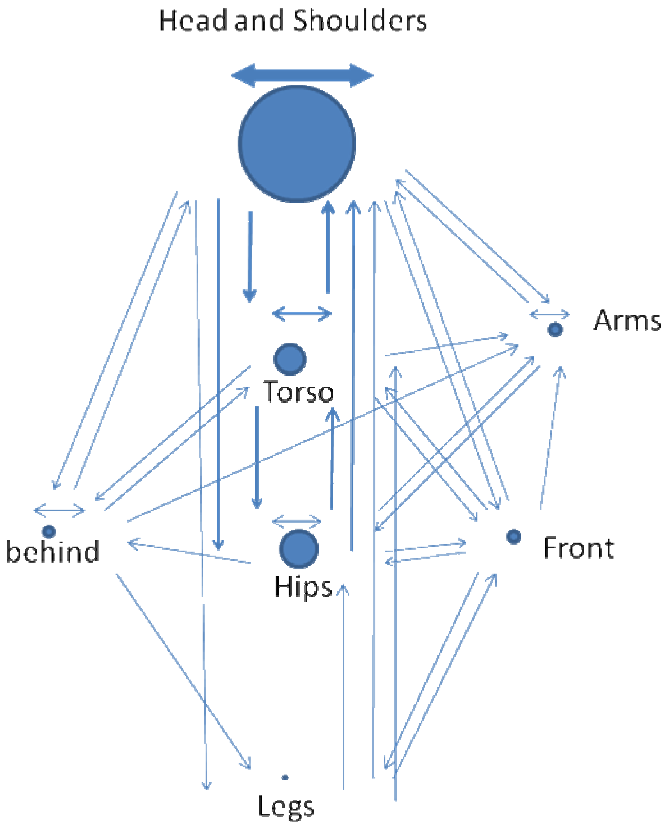

Figure 5.1: Novices' scan path

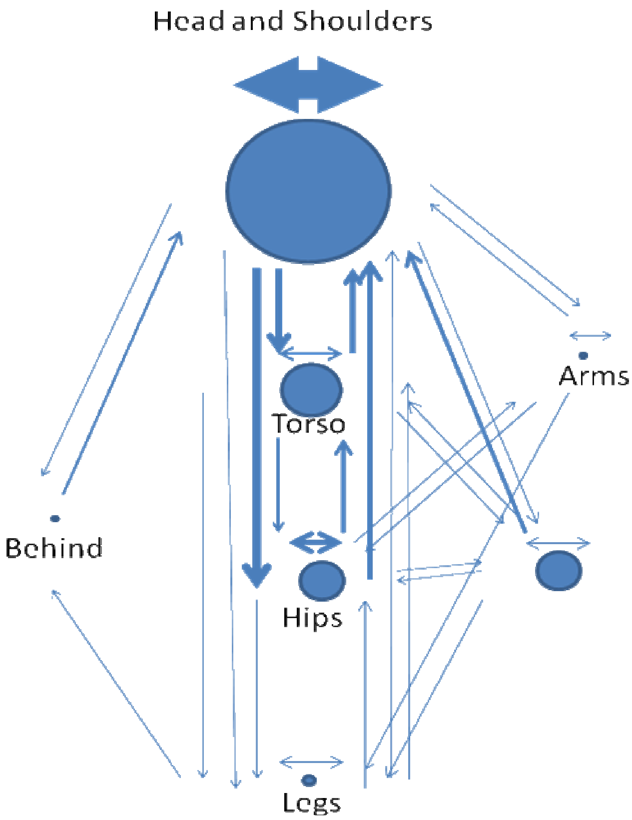

Figure 5.2: Experts' scan path

The scan paths show subtle differences between the experts and novices. Most noticeably the experts switched fixations from head and shoulders and then back to the head and shoulders more times than the novices represented by the wide arrows above the head and shoulders. In addition the experts switched fixations from head and shoulders to torso, from hips to torso and from head and shoulders to torso more than the novices. The wider arrows in figure 5.2 demonstrate that the experts had less random scan patterns than the novice participants. In addition, the circle sizes, relating to the amount of time fixating on each of the areas, suggest that experts spent more time fixating on the head and shoulders and torso than the novices.

5.4 DISCUSSION

This study used eye-tracking to examine differences in visual search between expert and novice coaches and judges when viewing the handspring vault. It was hypothesised that experts will produce significantly less fixations than novices per vault, experts will produce significantly longer fixation durations per vault, experts will fixate on fewer locations per vault and experts will produce significantly different scores to novices.

The results suggest that experts produced more fixations than novices when viewing handspring vaults and therefore do not support hypothesis one. This finding suggests that when judging the handspring vault, experts require more fixations in order to produce a coherent representation of the display. The finding that experts produced more fixations than novices has been corroborated by Goulet et al. (1989), Moran et al. (2002), Williams and Elliot (1999), Williams and Davids (1998), and Williams et al. (1994) who also found that experts produced more fixations when completing a variety of tasks. However, other research has found that novices produce more fixations than experts (Bard & Fleury, 1976; Helsen & Pauwels, 1992, 1993; Moreno et al., 2002; Ripoll et al., 1995; Singer et al., 1996;

Savelsbergh et al., 2002; Vickers, 1996a, b). These contradictory result can be explained through the degrees of perceptual (the speed and noise within the display) and cognitive complexity (the amount of decision making required during the task). Each study has differing cognitive and perceptual complexity which impacts upon the visual search findings. In addition, the studies also have with differing dependent variables, and as such it seems that different tasks require differing numbers of fixations (see section 2.5.2.1 for a review).

Surprisingly, the present results contradict those of Moreno et al. (2002), who also worked with a gymnastics coach population. Moreno et al. (2002) found that experienced coaches produced significantly less fixations than novices. The low mean score for the novices found in the present study reflects an increased period of search time (during saccades) in which the novices were not able to pick up information, thus having the potential to impact upon the decision making process. Novices therefore spent more time searching for the perceived areas of importance, and less time fixating on the informative areas of the display that would enhance the analysis of the movements. It seems that novices search patterns were more exhaustive and therefore the novices were not aware of where the most important information was. This is reflected in the more random scan paths produced by the novices (see figure 5.1).

The finding that experts have more refined eye tracking patterns seems to be the underpinning trend in much of the expert-novice literature, and as a result the reference to novices not being aware of important areas of the display is frequently cited (Abernethy & Russell, 1987; Ripoll et al., 1995; Williams & Davids, 1998). The experts produced a mean number of 6.65 fixations in the current study and 7.28 in the Moreno et al. (2002) showing low variation despite differing tasks being used within the studies (vault and floor routine). Another reason for the difference between the current findings and those in the Moreno et al. (2002) study may be because when performing on the vault the gymnast needs a faster run up and the handspring itself is faster. Therefore novices may have had problems anchoring their vision on specific parts because the display moves more quickly and could therefore be considered more complex.

The differences in visual fixation number between the two studies may also be as a result of the different methods used in the studies. The definition of fixation in the current study relates to tracking areas of the body (visual pursuit), whereas, fixations in the Moreno et al. (2002) literature relates to the eye being stationary. The eye therefore did not need to be stationary in the current study for a fixation to take place. Also the handspring vault is a very quick discrete skill, where as a floor routine, as used by Moreno et al. (2002) is made up of serial skills, thus their findings may not be generalisable to the discrete skill situation. The quick, dynamic display used in the current study may have also made it difficult for the observers to fixate or track the relevant areas of the body.

The results of the study support hypothesis two, suggesting that experts produce longer fixation durations than novices. This finding has been replicated by a number of research studies including Helsen and Pauwels (1992, 93), Moreno et al. (2002), Ripoll et al. (1995), Savelsbergh et al. (2002), and Vickers (1996a,b). The longer fixation durations produced by the experts in this study suggests that they were better able to track specific body parts for longer periods of time. This tracking relates to smooth visual pursuit which is a smooth eye movement that acts to keep a moving object foveated (Moran et al., 2002; Yang, Dempere-Marco, Hu & Rowe, 2002). The increased duration of the fixations (and therefore visual pursuit) may also allow the experts to produce a more coherent representation of a very complex display, in order to compare the movement with their model of correctness stored in the LTM. These results have not been supported in all the literature. For example, Williams and Davids (1998) and Williams et al. (1994) found that experts in soccer produced shorter fixations than novices. Such discrepancies suggest that fixation duration requirements are task-specific. Interestingly, Moreno et al. (2002) found that expert coaches in gymnastics produced longer fixation durations than inexperienced coaches. The consistency in these findings suggests that expertise in the observation of specific gymnastics skills require fixations of longer duration. However, it is not possible to report the extent of the similarities, as the mean fixation durations are not reported by Moreno et al. (2002).

Experts fixated on significantly fewer areas than novices showing support for hypothesis three. This is supported by Savelsbergh et al. (2002) who found that expert football goalkeepers fixated on fewer areas per trial in penalty scenarios. The expert and novice coaches and judges fixated most on the head and shoulder area, and as such may view these areas as most important in the decision making process. Despite some differences in percentage time fixating on each of the eight areas, there were no significant difference between the experts and novices. However, the findings suggest that experts spent more time fixating in front of the gymnasts. This may suggest that experts anticipate what will happen when scoring the vault and therefore move their eyes ahead of the action. This may reflect their ability to utilise their peripheral vision to pick up cues regarding the motion of the gymnasts. However, the percentage times were statistically the same suggesting that experts and novices utilise similar areas of the display, but the ways in which the information is used may be the key difference between the experts and novices (Abernethy, 1990).

The scan paths suggest that experts may view the head/ shoulder, torso and in front of the gymnast as three important areas for decision making (based on the three areas showing the highest % time fixated), whereas novices may view only the head / shoulder and hip as the important areas for decision making (based upon the two areas showing the highest percentage time fixated). Additionally, experts appear to scan more between the head and shoulders to the hips, and from the hips to the heads and shoulders more than the novices, suggesting that this may be a key pathway for gathering information.

Interestingly, despite the three visually-based dependent variables showing significant differences between the expert and novice participants, there were no significant differences in the judgments produced by experts and novices ($p=0.343$), this finding was also supported by Ste-Marie (1999). One may then question whether the significant differences presented above are relevant given that the experts and novices came to the same conclusions regardless of the differences in visual search. However, in general, studies investigating perceptual expertise (Goulet et al., 1989) suggest that experts complete visual tasks more efficiently than novices. Therefore understanding the visual search variables that underlie performance could be considered as important given the potential benefits of developing more proficient solutions to problems. Furthermore, although the scores were not significantly different, there was a 0.31 mean mark difference which can have a considerable effect on gymnasts' rankings during competitions. For example, in the 2008 British Championships 0.30 marks separated 1st and 4th place showing that although the score differences not statistically significant, they may be contextually different enough to make a difference to a gymnastics competition.

The lack of statistically significant differences in the scores could be explained by four important factors. Firstly, the experts and novices produced high standard deviations showing high variability about the mean (0.70 & 0.69 respectively) (Savelsbergh et al., 2002), and the sample size was small (Savelsbergh et al., 2002) which could conceal any difference in the data. Secondly, a relatively easy skill was scored (handspring vault) and the quality of the performance was similar each time the vault was performed which may have resulted in all coaches and judges being capable of making informed decisions about the task. Thirdly, this finding questions the use of coaching and judging qualifications as discriminators of expert and novices. It may be that experience in the sport could cause greater discrepancies. For example, a coach could be a novice with an assistant club coach qualification, but they might have been competing at an elite standard for many years. This variation should be explored in future studies. Finally, the coaches and judges in this study did not use the allowable range of the judging scale from zero to ten. For example, 82% of scores were inside the six to eight range, suggesting that the potential range of judging scale was not utilised by the coaches and judges in this study and therefore the mean scores are similar. A problem with a restricted range on a variable is that it impacts on any inferential statistics undertaken with that variable and therefore significant differences are unlikely to be detected.

However, visual differences were the main focus of this study and differences were found in all three of the visual search variables (number of fixations, fixation duration, number of areas fixated) between the experts and novices. In addition, the partial eta squared effect sizes suggest that the differences between the visual search of the experts and novices were large (number of fixations $\eta^2 = .69$, fixation duration $\eta^2 = .54$, number of areas fixated $\eta^2 = .38$) showing that a large amount of the variance in the visual search variables is explained by the independent variable (experience).

In conclusion, this research aimed to add to the literature into the role of eye movements in visual perception that has been carried out in sport. The findings suggest that the search patterns of experts and novice coaches and judges while studying the same footage are significantly different but bear some common characteristics in terms of percentage time fixating on the eight identified areas. The findings provide support for the conclusion that the limiting factor in the perceptual performance of novices is an inappropriate search strategy. However, the similarities in fixation location suggest that novices may not be able to make full use of the information available from fixated display features. This would suggest weaknesses in categorisation and information integration, which is primarily driven by knowledge stored in the long-term memory (LTM) (Bless et al., 2004) and therefore differences between experts and novices search strategy may be as a result of the limited declarative knowledge stored by the novices". Interestingly, many researchers have found that experts also have greater declarative, procedural and strategic knowledge about their sports (French, Spurgeon & Nevett, 1995; McPherson, 1993,1994). Thus a combination of this knowledge may provide the most effective training method for advancing the performance of novices. An in-depth study of experts' visual search and knowledge may enable the development of perceptual training aids which consequently may help develop the decision making skills of novice coaches and judges.

An Exploration of Expert Coaches' and Judges' Knowledge and Visual Search Patterns

This chapter reports the findings of a study designed to examine the visual search patterns and knowledge base of expert coaches and judges. This study is designed to meet aim three of the research project and the information gained from the study will be used to inform the development of perceptual training videos used as an intervention for study four

Portions of this study have been presented at the 12th European Congress of Sport Psychology (FEPSAC). Halkidiki, Greece, 2007

This study combined with the data from study four has been accepted for the 12th ISSP World Congress of Sport Psychology. Marrakesh, 2009

6.1 INTRODUCTION

The enhanced cognitive knowledge base and enhanced strategic processing of information that underlies experts perceptual skill enables experts to effectively deal with performance scenarios similar to those previously experienced (Ericsson & Kintsch, 1995). This superiority appears to be primarily developed as a result of sport specific experience and being actively involved in playing and practising the sport. This is opposed to inactive observation (Williams & Davids, 1995; Helsen, Hodges, Starkes & Van Winckel, 2000) or as a result of development or maturation (Abernethy, 1988). Therefore, the emphasis for sports researchers is to understand the development of cognitive expertise, examining the link between what is observed and the translation of this into useful information for the performer.

Williams and Grant (1999) suggest that “a detailed understanding of the specific sources of information employed during skilled perception is an essential prerequisite to the development of effective perceptual training in sport” (p.211). The ‘detailed understanding’ pre-requisite has been interpreted by researchers in a variety of ways which has meant that perceptual training aids utilised in previous research have varied in their detail and quality. Côté et al. (1995a) propose that one method of investigating the complex domain of expertise, such as in high level coaching, might be to employ a reality-grounded approach which is often developed using inductive processes.

This study focuses on identifying the cues and knowledge used by coaches and judges when analysing performance. It will use semi-structured interviews and visual search patterns to elicit the key elements and verbalise the knowledge experts perceive as important for dealing with real-life situations in their domain.

Findings from the visual search research in sport suggest that experts and novices have different visual search patterns (see sections 2.5.2.1 to 2.5.2.5 for a full review of this literature). In addition, study two found that there were significant differences in number of fixations ($F_{(1,19)}$ 40.706, $p<0.05$), fixation duration ($F_{(1,19)}$ 15.606, $p<0.05$) and number of areas fixated ($F_{(1,19)} =4.873$, $p<0.05$) between expert and novice coaches and judges in gymnastics. However, knowledge of full gaze behaviour does not necessarily provide exhaustive information on which stimuli are actually perceived, because experts may respond to peripheral and foveal stimuli when controlling their behaviour (Williams et al., 1999). Indeed, Hawkey and Williams (2007) found that a variety of biomechanical factors at each stage of the handspring vault predicted the final score given by judges. Information input may also be influenced by orienting attention toward peripheral stimuli, despite fixating on other areas (Posner, 1980). Thus visual fixations do not always directly relate to attention (or cue extraction). This has led researchers to refer to visual fixations as ‘looking’ and cue extraction as ‘seeing’ (Abernethy, 1988; van der Heijden, 1986).

Interestingly, much of the visual search research (Bard & Fleury, 1976; Ripoll et al., 1995; Savelsbergh et al., 2002; Ward, Williams & Bennett, 2002; Williams & Davids, 1998) has identified times where performers did not anchor their vision on pre-defined specified areas of the display and consequently may have used peripheral vision to analyse the performance (Williams & Davids, 1998). In addition, it seems that attention can be moved around the visual field without making distinctive eye movements to change the point of fixation (Jonides, 1981; Sanders & Houtsman, 1985). Therefore reliance only on foveal fixation data may not be detailed enough to produce informed training videos for coaches and judges. Indeed, Williams and Davids (1997) highlighted the need to combine eye movement registration techniques with parallel measures of information extraction when attempting to understand the perceptual strategies employed by performers.

Another way of developing the link between what is observed and visual attention is through verbal report. “Verbal report procedures require participants to verbalise the area of the display that they consider to be particularly informative” (Williams & Davids, 1997, p.365). Previous research has used methods based on cognitive anthropology (Agar, 1983; Spradley, 1979) and grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1990) in order to identify a knowledge domain representing coaching expertise in gymnastics (see Côté et al., 1995a). Côté et al., (1995 a,b) conducted two studies, one investigating training and competition considerations and another examining methodological frameworks of gymnastic coaches’ knowledge. Interestingly, within the methodological framework study (Côté et al., 1995a), contextual information was cited as a way of developing elite athletes. This implies that the inclusion of contextual information in LTM contributes to the coaching process, and should therefore be explored when determining expert knowledge bases. However, Moran et al. (2002) suggest that experts' insights into their own visual search behaviour are not always accurate, and therefore a combination of techniques may be most appropriate for training purposes.

Research has suggested that the existence of domain-related knowledge significantly improves the performance of children in memory tasks (Chi & Koeske, 1983; Ornstein & Naus, 1985). French and Thomas (1987) examined the relationship of sport-specific knowledge to the development of children's skills in basketball. They found that basketball knowledge was a significant predictor of the decision-making component at the end of a basketball season. They concluded that the development of the sport knowledge base plays a salient role in skilled sport performance of children suggesting that enhanced knowledge may lead to enhanced decision making.

Research has consistently found that experts have superior contextual knowledge than novices (Abernethy, Neal & Koning, 1994; Adelson, 1984;

Chi & Glaser, 1980; Chi et al., 1981). Williams et al. (1999) suggest that more elaborate task-specific knowledge bases allow performers to interpret events encountered in circumstances similar to those previously experienced. Williams et al. (1999) state that the `knowledge structures', direct players' visual search strategies towards more pertinent areas of the display based on their expectations and the more effective processing of contextual information (e.g., pattern recognition, advance cue utilization, see section 2.3.1.3 for a review of these concepts).

Although some researchers have had success combining verbal report and eye movement recording data (Buckolz, Prapavesis & Fairs, 1988), others have found that verbal reports are ineffective in identifying cognitive processing (Le Plat & Hoc, 1981). However, most cognitive psychologists agree that if used appropriately verbal reports can provide valuable insights into cognitive processing (Williams & Davids, 1997). A specific issue to consider is the timing with which the eye-patterns and knowledge bases are used. Goulet et al. (1989) investigated visual search patterns when preparing to return tennis serves and found that both expert and novices were looking at different cues in the preparation, ritual and execution phases. They also found that experts selected valuable information at the preparatory phase and identified more serves correctly than novices. Savelsbergh et al. (2002) found differences between expert and novice goalkeepers' fixation locations at times leading up to the penalty. This implies that it was not only the cues that were important, but also the time of looking at such cues. This is also reflected in the fixation-suppression hypothesis forwarded by Vickers (1996b). Therefore the present research aimed to collect rich data sets at specific time frames, to provide more exhaustive information regarding practical training implications.

Given the differences between expert and novice visual search patterns (e.g., Goulet et al., 1989; Moran et al., 2002; Williams & Davids, 1998; Williams & Elliot, 1999; Williams et al., 1994, study two) and the differences between expert and novice knowledge bases (Abernethy et al.,1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981; Ste-Marie, 1999; Williams et al., 1999) it seems logical that gaining a detailed understand of visual search and knowledge in expert gymnastic coaches and judges may aid the subsequent training of judgment formation. Therefore this study aims to understand what expert gymnastic coaches and judges fixate upon and look for in the handspring vault using eye-tracking procedures and follow up semi-structured interviews. Specifically, this study aims to determine the number of fixations, fixation durations and fixation locations of expert coaches and judges during the five phases of a handspring vault (run-up, hurdle step, first flight, second flight and landing). In addition, it will also identify what knowledge drives their attention process during the five phases using a video which is able to be reviewed as many times as necessary.

6.2 METHOD

6.2.1 Participants

Recruitment of participants was through personal contact; this included letters and telephone calls. Gymnastic coaches and judges (n = 9) were recruited through British Gymnastics. However, one participant's data was lost due to data capture errors (see section 4.2.1 for an explanation of the data capture errors) therefore this convenience sampling method led to eight participants completing the study. Due to the nature of the study inclusion criteria were that they were experienced to at least high performance woman's artistic coach or regional judge (mean age of 52.0 ± 14.92 years, and mean experience of 23.75 ± 13.57 years). All participants provided written informed consent prior to initiating the study (appendix 1) having read an information sheet (appendix 8), and ethical clearance was provided by the University Ethics board.

6.2.2 Test film – eye tracking

The videotape was created from footage collected at two gymnastics clubs' training sessions, filmed from a position representing where a judge would be sat in competition. This own-point-of view recording provides minimum distortion of the complexity and dynamics of naturalistic environments (Omodei et al., 1998), thus increasing physical fidelity (Lintern et al., 1989). Eleven videotaped gymnastic vaults were used in the study. One of the eleven was used as a test stimulus to familiarise participants with the procedure. All vaults were handsprings, representing what a lower level judge might see in competition.

6.2.3 Test film – interview

The test film for the interview included the same vaults as the eye-tracking video. However, the format included each vault twice. The first viewing was to enable the observers to see the entire vault and the second was to allow the observers to track backwards and forwards in order to respond to questions regarding specific areas of the vault. This method overcomes the problems of retrospective recall identified by Hanton and Jones (1999) such as not remembering what they were looking for and how each vault developed having watched them previously. The first vault was a test vault and allowed the researcher to show the participants the procedure for the following ten vaults.

6.2.4 Procedure

Participants were tested individually either in a Motor Skills Laboratory or at specific gymnastics clubs using an identical set-up. One week prior to testing each participant was sent an information sheet (appendix 8) and a copy of the previously developed scoring system (appendix 3). Participants were asked to familiarise themselves with this.

Upon arrival, the nature of the study and the methods of data collection were explained to each participant. To reduce researcher bias the study was explained using a pre-designed prompt sheet to ensure each participant received the same information and instructions. Participants were informed that initially they would be watching and subsequently judging using the previously supplied criteria to score a series of handspring vaults presented in a randomised order. Following this they would be asked to watch a video with the same vaults and complete an interview designed to elicit information regarding decision making and attention. When all questions had been answered participants gave informed consent, both verbally and in writing (appendix 1). Once consent had been gained each participant completed a demographic questionnaire relating to coaching and judging experience, years within the sport and roles.

6.2.4.1 Visual search

Visual search patterns were collected prior to each interview. Participants were seated and the ASL 501 eye tracker fitted. Prior to commencement of the test film participants were reminded that they were to view eleven vaults and assign a score to each one. They were also informed that there was time between each vault to verbalise their score. The assigned score was noted on a results sheet by the researcher. Once it was clear that all instructions had been understood testing commenced starting with a nine-point calibration (figure 3.6). During testing the participants were not given information regarding the nature of the performers to avoid any expectation bias (Ansorge et al., 1978) and the Hawthorne effect (Thomas et al., 2005). The gymnasts were not known to the participants to prevent reputation effects (Findlay & Ste-Marie, 2004). Upon completion of data gathering each participant was debriefed during which questions focused upon how they felt about the testing protocol and comfort of the eye tracking headgear. No discussion took place regarding the vaults and their scoring performances to reduce bias in the interview.

After the visual search data collection, participants were seated approximately one metre away from a television unit and were given an information sheet explaining what they were going to be asked to do (appendix 8).

6.2.4.2 Interviews

Immediately following the collection of the eye-tracking data, each participant took part in a semi-structured interview (Côté, Salmela, Trudel, Baria & Russell, 1995). Each participant was asked a sequence of questions relating to the information used to form a judgment, based on the work of MacMahon and Ste-Marie (2002) (See appendix 9 for the interview guide). Questions were related to 1) What information did you use to help formulate the score during the (run up) phase? 2) Where did you look to get this information? and 3) Why did you look there? In addition to this, elaboration probes were used where necessary to ensure consistent depth of questioning across interviews. Elaboration probes are useful to help clarify or expand answers, a technique suggested by Patton (1990) and used in earlier qualitative sport psychology research (e.g.,, Anshel & Kaissidis, 1997; Gould, Eklund & Jackson 1993a, Gould, Finch & Jackson, 1993b; Kaissidis-Rodafinos, Anshel & Porter, 1997; Scanlan, Stein & Ravizza, 1991). This allowed some variation in the interview process, thus enhancing the chances of capturing the coaches and judges experiences in their entirety (Dale, 1996).

The interview questions were piloted on two occasions with lower level gymnastics coaches and judges and adjustments were made where necessary. This allowed the researcher to examine if the questions were comprehensible, whether the method of recording them was practical, and how long each interview was likely to take (Foster & Parker, 1995). Each interview was audio-taped and transcribed verbatim (see appendix 10 for an example).

First the participants were shown the initial questions that they would be asked. Following this the participants were taken through an example test item. This involved the participant watching a video sequence while the experimenter demonstrated what questions would be asked throughout the different phases of the vaults. The video review technique aimed to reduce the memory decay and recall concerns reported by Hanton and

Jones (1999). At this time, the researcher answered any questions until the participant became accustomed to the procedure, as well as the structure of the videotape. Following this, the researcher began audio taping the verbal responses given for the subsequent ten test vaults.

Participants were tested individually and the interview was self-paced based on their responses. This resulted in testing sessions lasting from 45 to 70 minutes in duration.

6.2.5 Data Analysis

The eye-tracking and interview data were temporally analysed using five phases of the vault. With regards to the eye-tracking data the run up was recorded from the initiation of action to the final step in the run way. The hurdle step constituted the time after the final step until contact with the springboard. The first flight included the time from springboard contact to the hand contact on the vault. The second flight started when the hands were on the vault and continued until foot contact onto the floor, therefore also included in the repulsion off the vault. The landing phase included the time from foot contact on the floor until the initiation of the 'present'.

The raw interview data resulted in between 7 and 16 typed single spaced A4 pages per participant, resulting in 77 pages of data. The interview data were analysed using inductive content analysis (Biddle, Markland, Gilbourne, Chatzisarantis & Sparkes, 2001). This approach allowed the responses to be listed and subsequently grouped into interpretable and meaningful categories. Using the method of data analysis outlined by Biddle et al. (2001), data themes were developed from the raw statements. Common themes within the raw data were identified by grouping together similar statements and giving them a label that reflected the content and meaning of the raw data theme. Each response was compared with all the other responses, thereby allowing statements with similar or different meanings to be combined or separated.

First order and second order themes were developed based upon the raw statements. A consensual validation procedure took place whereby the primary supervisor (an expert in qualitative methods) read through the interview transcripts, and confirmed the first and second order themes. Any discrepancies were discussed and resolved through discussion (Bruner, Munroe-Chandler & Spink, 2008).

After the inductive content analysis was complete, each second order theme was examined to ensure that the raw statements that made up the second order theme had been suggested by over 50% of the participant for over 50% of the vaults. An arbitrary quantitative 50% cut-off rule was applied in order to create a coherent training programme that was representative of what was said by the experts rather than based on one expert's idiosyncratic ideas on what constituted a good vault.

The visual search data were analysed using fixation number, fixation duration and fixation locations for each of the five phases of the vault. Only fixations that were made by more than 50% of the participants in a specific area for more than 50% of the vaults were used in the analysis (see section 6.3.1 for actual values). The hurdle step, first flight and second flight were combined in the analysis as the viewing time at each phase was very limited (hurdle step mean=212ms, 1st flight mean=212ms, 2nd flight mean=370ms) compared to the run up and landing (mean=1026ms & mean=696ms respectively), and therefore no pattern could be seen when analysed as discrete phases. This pattern analysis aimed to represent what observers 'normally' fixate on when observing a performance.

6.3 RESULTS

The visual fixation data, including fixation location, fixation duration and number of fixations, and inductive content analyses are presented below.

6.3.1 Visual Fixations

The mean data per vault are presented followed by a breakdown of the five phases of the vault.

6.3.1.1 Mean data per vault

Table 6.1: Experts mean number of fixations, fixation duration, number of areas fixated and outcome judgment per vault.

Dependent variable	Mean
Number of fixations	7.0
Fixation duration (ms)	190.15
Number of areas fixated	3
Outcome judgment	8.42

6.3.1.3 Phase analysis

6.3.1.3.1 Run up

The visual search data showed that for 75% of the observers for 90% of the vaults the fixations were on the shoulders during the run-up. The mean duration for the fixations on the shoulders during the run up was 229.41ms. The mean number of fixations on the shoulders during in the run up was two (see Table 6.1).

6.3.1.3.2 Hurdle step, first flight, and second flight

The visual search data showed that for 75% of the observers for 60% of the vaults the fixations were on the torso during the hurdle step, first flight, and second flight. The mean duration of the fixations on the torso during the hurdle step, first flight, and second flight was 162.61ms. The mean number of fixations on the torso in the hurdle step, first flight, and second flight was on three, with on average one fixation in each phase (see Table 6.1).

6.3.1.3.3 Landing

The visual search data showed that for 62.5% of the observers for 90% of the vaults the fixations were on the shoulders during the landing. The mean duration for the fixations on the shoulders during the landing was 211.43ms. The mean number of fixations on the shoulders during in the landing was one (see Table 6.1). The visual search data showed that for 62.5% and above of the observers for 70% of the vaults the fixations were on the torso during the landing. The mean duration for the fixations on the torso during the landing was 212.26ms. The mean number of fixations on the torso during the landing was one (see Table 6.1).

Table 6.2: Experts mean number of fixations, fixation duration, number of areas fixated and outcome judgment per phase of the vault.

Phase	Run up	Hurdle step	First flight	Second flight	Landing	
Fixation Location	Shoulders	Torso			Shoulders	Torso
Number of areas	1	1	1	1	2	
Mean duration (ms)	229.41 [118.93]	162.61 [43.91]			211.43 [118.72]	212.26 [92.92]
Mean Number	2	3 (1 per phase)			1	1

* [ ] refers to the Standard Deviations.

These data reinforce the percentage time data from study two suggesting that experts fixate most of their time on the shoulder and torso regions. More specifically these data are time-based and show at what time-point in time these locations are fixated throughout the handspring vault. The longest fixation took place during the run up phase and these fixations were predominantly on the shoulders of the gymnasts.

6.3.2 Interview data

The extrapolation of raw data statements for the transcripts yielded a total of 97 meaning units across the five vault phases. Discrete meaning units of similar themes were grouped together to produce first order and second order themes. Hierarchical trees for each of the phases are shown in figures 6.1 to 6.5

Run up

Raw themes	**First order themes**	**Second order themes**
Dynamic run up (4)	Dynamic	
Run up's not too dynamic is it (7)	Not dynamic	Dynamic
There's no interruption in the run (5)	Interruption	
Try and address the power (3)	Power	
I'm looking for is a dynamic run up (3)	Vision	
You know you've got to accelerate (9)	Acceleration	
She had a slow run (13)	Slow run up	
She's slowing down (11)	Deceleration	Fast
Very much faster (12)	Fast run up	
If you are looking for a fast run she should be leaning back Ready to drive and she's already half a step forward	Preparation	
She's quite long legged she should be able to get a fair Speed (4)	Expectations	
Usually the speed of the arms is related to the feet (8)	Arms related to speed	
Good arm action though, she pumps the arms nicely (3)	Arm pump	
I'm also looking for the arms driving (15)	Drive	
Arms are quite straight (3)	Straight	
She doesn't use her arms very much (16)	Non use of arms	Powerful arm pump
Elbows coming out to the side of the body rather than staying Close (4)	Technical	
Arm actions good (15)	Good action	
Bent elbows (9)	Bent elbows	
Arms are aren't as efficient as they should be (14)	Not efficient	

Number in brackets represents the number of times each statement was said.

Figure 6.1 Meaning units, first order and second order themes produced in relation to the run up phase of the handspring vault

Hurdle step

Raw themes	**First order themes**	**Second order themes**
Leaning back slightly rather than attacking it. (2)	more upright	Body leant Back
She's landing too upright on the board (17)	Too upright	
That's good position (8)	Good position	
That's a reasonable position to be (3)	Reasonable position	
Her centre of gravity is well back so you're now Going to get a pivot action (7)	Centre of gravity	
She is almost upright here see (5)	Upright	
Too far forward (3)	Too far forward	Feet on springiest Part
When you're at the top of the board you get much More out of the springboard (8)	Springiest part	
Good position on the board (8)	Good position	
Top of the board (3)	On top	
That position when she hit the board wasn't too bad (5)	Reasonable position	
Teach them to keep their arms behind when they Hit the board (17)	Arms should be behind	Big powerful Arm swing
She gathers herself here (3)	Gathers herself	
There's no arms swing (3)	No arm swing	
See the powerful arm swing (3)	Powerful arm swing	
She just lifting them forward a bit soon (3)	Swing too early	
Arm circle's good (7)	Good arm circle	
Massive arms swing (4)	Big arm swing	
Doesn't really swing her arms from back to front.	Should swing forwards	
She sends them around	Arms swing from side	

Number in brackets represents the number of times each statement was said.

Figure 6.2: Meaning units, first order and second order themes produced in relation to the hurdle step phase of the handspring vault

First Flight

Raw themes	**First order themes**	**Second order themes**
You’re expecting to see a stretched body shape on (3)	Stretched	
Feet should be here for a extended shape (7)	Technical	Stretched body
As she took off she was leaning forward (6)	Leaning	
Good shape (8)	Good shape	
She was piked as she came on (16)	Pike on	
She kept nice and straight (8)	Straight	
Her hip angles piked (6)	Hip angle	Straight
A bit piked so she would lose on that (4)	Deductions	body
Not too much pike (4)	No pike	
She came off quite piked	Pike off	
She's not lifting her heels, she's lifted her bottom (4)	Bottom	
Strong heel drive (8)	strong drive	
Faster with her heels (18)	Quick heel drive	Quick heel drive
No heel lift or rotation of the feet (12)	No heel drive	
I'm looking at the heels now (4)	Vision	

Number in brackets represents the number of times each statement was said.

Figure 6.3: Meaning units, first order and second order themes produced in relation to the first flight phase of the handspring vault

Second flight

Raw themes	**First order themes**	**Second order themes**
No push (17)	No push off	Good push off
Good push off (13)	Good push off	
Shoulders are slightly forward and the not going to get An efficient push off (6)	Shoulders	
Really the push off should go towards this way (2)	Direction of push	
Little push off (9)	Limited push off	
She's been in contact with the horse for all that time (5)	Hand contact	
Haven't got the um efficient push off the vault	Push off	
Limited flight (10)	Limited flight	Height & distance
No flight off (9)	No flight	
She's come on quite high her angle here is Going to be straight down which (3)	Angle of flight	
It'll now just drop off (15)	Drop off	
You are looking for is height and distance (4)	Height and distance	
The flight is good (6)	Good flight	
Reasonable flight (5)	Reasonable flight	
Nice dish shape into land (7)	Dish shape	Straight body
Her body's fairly straight (i4)	Straight body	
Not in an exact handstand (4)	No handstand	
Shoulders just behind just following her feet gradually (5)	Shoulders	
A good body shape (8)	Good body shape	
Not a bad shape (6)	Reasonable body shape	
Her feet are in front which is right (3)	Feet	
Probably a bit too much of a snap off there in Terms of the body shape (6)	Not straight	
She has no extension to stand up (2)	No extension	
Bent arms unfortunately (22)	Bent arms	Straight arms
She had to push off her elbows	Elbows	
Straight arms (8)	Straight arms	
I'd still want the arms further back (2)	Arm position	

Number in brackets represents the number of times each statement was said.

Figure 6.4: Meaning units, first order and second order themes produced in relation to the second flight phase of the handspring vault

Landing

Raw themes	**First order themes**	**Second order themes**
Spot the landing (6)	Spotted landing	Stepping
Little hop forward, but I would expect that in the crash mat (3)	Landing surface	
Having to take a step (13)	Take a step	
Quite a large step (6)	Large step	
She needs to take a step backwards (7)	Step backwards	
Maybe possibly 0.3 for the step (4)	Deductions	
Results in a deep squat (6)	Deep squat	Squat
Deep squat 0.1 (5)	Deductions	
Low flight had lead to a deep squat on landing (3)	Flight	
Bend in the knees (7)	Knees	
Hips down over the heels (2)	Hips	
She can't stand up when she lands (4)	Momentum	Control
If she'd just lifted her chest up a little bit more (7)	Body Alignment	
Stability of landing (5)	Stability of landing	
She's got that rotational drive (2)	Rotation	
But she's still determined to do it (6)	Fighting it	
Because she's working hard with her upper body (4)	Upper body	

Number in brackets represents the number of times each statement was said.

Figure 6.5: Meaning units, first order and second order themes produced in relation to the landing phase of the handspring vault

To summarise, the interview data produced the following second order themes (see Table 6.3), based on raw statements said by 50% and above of the observers for more than 50% of the vaults. Two second order themes were removed from the analysis because they did not meet these criteria.

Table 6.3: Second order themes identified during each phase of the vault.

Phase	Second order themes
Run up:	Dynamic Fast Powerful arm pump
Hurdle step:	Body leaning back Feet on springiest part Powerful arm swing
First flight:	Stretched body Straight body Quick heel drive
Second flight:	Good push off Height and distance Straight body Straight arms
Landing:	Control Stepping Squat

6.3.3 Integration of fixation and interview data

6.3.3.1 Run up.

These visual fixation data suggest that experts fixated mainly on the shoulders during the run up phase. The knowledge that the experts used in the run up related to the speed, dynamics, and powerful arm pump. For example with respect to the run up participants reported ‘I'm generally looking at the run up to see how dynamic the run up is’ ‘I’m looking to see some acceleration’ and ‘she needed a good powerful arm pump’.

6.3.3.2 Hurdle step

These data show that experts fixated on the torso during the hurdle step phase. The interviews suggest that the angle of body on board, foot position on board and arm swing are the most important parts of the hurdle step phase. In relation to the hurdle step participants suggested that ‘I'm looking for the position of the body on the springboard’ ‘when you're at the top of the board you get much more out of the springboard’ and ‘arm position to the horse are above the head rather than being down by the body which is where they should be at the moment swinging upwards and forward, they're going to swing downwards from there’.

6.3.3.3 First flight

During the first flight phase the experts fixated on the torso. The interviews suggest that a stretched and straight body and the speed of the heel drive are the most important parts of the first flight phase. The participants suggested that they would like to see ‘a nice straight or slightly dished body shape coming on’ with a ‘quick heel drive’.

6.3.3.4 Second flight

These visual fixation data suggest that experts fixated on the torso during the second flight phase. The interviews suggest that the push off, height and distance, stretched body shape and straight arms are the most important parts of the second flight phase. This is supported by statements from the participants suggesting that ‘a bit more dish shaped would help’ ‘what you are looking for is height and distance’ and ‘her arms are bent in support’.

6.3.3.5 Landing

During the landing phase the experts fixated on the shoulders, and torso. The interviews suggest that control, stepping and squatting are considered as important in the landing phase. This is supported by statements such as ‘deep squat when she lands because of the shape she's come off’ ‘she's managed to stabilise the landing’ and ‘good landing without any steps’.

6.4 DISCUSSION

The aim of this study was to investigate the visual search patterns of expert coaches and judges in order to inform a perceptual training programme. To achieve this expert coaches and judges watched a series of ten vaults and their eye tracking patterns were recorded. To enhance the quality of the perceptual training programme, as suggested by Williams and Davids (1995) declarative knowledge used to determine the quality of each vault was also assessed. This was important as training programmes that include only the number and duration of the fixations, may not enable the lower level judges to make more accurate decisions, because the experts may have been using the periphery to detect important information (Posner, 1980) which is not picked up through the eye-tracker.

To address this issue, as suggested by Williams and Davids (1997), interviews were carried out with each coach and judge to examine what they were looking for during each phase of the vault. This data was collected in order to understand the knowledge that the experts were using when analysing the vaults. Many of the second order themes produced throughout the five stages of the handspring vault relate to biomechanical elements, for example, speed of arm pump in the run up and straight body angle in the second flight. The use of biomechanical information by experts supports the work of Ste-Marie (1999) who suggested that novice gymnastic judges should be taught biomechanical information to enhance their expertise.

The combined visual search and interview findings suggest that one visual fixation location can lead coaches and judges to analyse several different aspects of the vault. For example, in the run up it seems that experts fixated on the shoulders but were able to analyse information relating to dynamics, speed and arm pumps. This suggests that experts limit the information processing load by using one or two areas of input (fixations on shoulders and torso) to process information regarding the quality of three or four areas, dependant on the various stages of the vault. A reduced information processing load is often characteristic of experts and is reflected by a low number of fixations (Williams et al., 1999). However, the novices in study two produced fewer fixations than experts suggesting that they may have a decreased information processing load (Williams et al., 1999).

It seems that novice coaches and judges may have tried to limit their information processing to such an extent that their input does not include enough relevant cues in order to select the best response. This study suggests that the optimum information processing load for gymnastic coaches and judges relates to one to two bits of visual information per phase (as identified by the fixation location data), with three to four areas that need to be processed per phase (as identified from their declarative knowledge). This suggests that experts may fixate on a central location or anchor their vision to central areas (Williams & Davids, 2007), such as the torso, using their central vision (1 to 2 degrees of visual angle) and then employ peripheral vision (160 degrees vertically and 200 degrees horizontally; Harrington, 1964) to monitor other areas of the display. For example, the participants fixated on the shoulders in the run up and suggested that they were looking for a powerful arm pump. The arms would fall within the peripheral field of view reported by Harrington (1964), suggesting that peripheral vision may be useful for detecting some aspects of the environment. This would seem relevant given that the retinal periphery is designed to detect motion (Milner & Goodale, 1995; Williams et al., 1999).

Many of the second order themes produced by the experts are consistent with the ‘Specific Execution Deductions’ which are the judging regulations produced by British Gymnastics, which state for example that insufficient dynamics carries between a 0.10 and 0.50 deduction. Experts in the present study reported that ''I'm generally looking at the run up to see how dynamic the run up is' 'the run's not very fast and dynamic' and 'her run up wasn't dynamic at all, if you look she was holding back'. These statements suggest that declarative knowledge in terms of the criteria used to assess the quality of a vault is also important for judgment formation. Therefore relaying such information to novices may aid the development of the judgment formation process.

Many of the findings in the present study support Ste-Marie (1999) who suggested that biomechanical information is important to attend to when assessing gymnastics performance. For example, this study found that the speed of the run up was important when analysing the handspring vault and Takei (1990) suggested that a large horizontal velocity was important for successful handspring vault, based on a biomechanical analysis of handspring vaults, displayed in the 1987 Pan American Games. In relation to the hurdle step, the experts in this study suggested 'when you're at the top of the board you get much more out of the springboard' and in support, Takei (1990) found that a large vertical velocity of touch down on the board was another important determinant of success for the handspring vaults.

However, the findings from the present study are not entirely consistent with the information published in the biomechanical literature on the handspring vault. For example, the hurdle step findings in this study are not consistent with Hawkey and Williams (2007). They found that time in contact with the board ($r=-0.724$, $R^2=0.524$, $P=0.001$) and step distance from board ($r=0.679$, $R^2=0.661$, $P=0.001$) were two of the five factors most highly correlated with the judges' score during the handspring vault whereas this study found that angle of the body on the board, foot position on the board and arm swing are the three things looked for in the huddle step. It could however be argued that step distance is related to foot positioning on the board and therefore the present study does show partial support for Hawkey and Williams (2007). However, the Hawkey and

Williams (2007) study was based upon a biomechanical analysis rather than a verbal analysis and this may account for the inconsistencies in these findings. In addition, the discrepancies between the studies could have been caused by 50% cut-off rule used in the analysis of the interview data in the present study, as this type of analysis could be influenced by small changes in the data set and therefore may have influenced the information that was included in the perceptual training programme.

Furthermore the interviews in the present study suggest that the push off, height and distance, stretched body shape (dish shape) and straight arms are the most important parts of the second flight phase. This is supported by statements from the participants suggesting that 'a bit more dish shaped would help' 'what you are looking for is height and distance' 'she pushes herself off there' and 'her arms are bent in support'. These finding also partially support Hawkey and Williams (2007), who found that the angle of the elbow at handstand ($r=0.676$, $R2=0.457$, $P=0.001$) and time in contact with the vault during the repulsion phase ($r=-0.732$, $R2=0.536$, $P=0.001$) were two of the five factors most highly correlated with the judges score during the handspring vault. Hawkey and Williams (2007) also found that time in the post-flight phase ($r=0.813$, $R2=0.661$, $P=0.001$) was highly correlated with the judges score during the handspring vault, this may be directly comparable with the height and distance (i.e., longer flight times suggest high and longer vault) second order themes which were considered important by the coaches and judges in this study.

Interestingly, for some of the phases in the vault there were distinct similarities with where the participants fixated and where they were looking for information, supporting Helsen and Starkes' (1999) conclusion that experts have a good meta-cognitive awareness of their own visual search. For example, in the run up the participants fixated on the shoulders, and suggested that the arm speed was important and in the first flight they fixated on the torso and suggested that having a straight body was important. This suggests that participants may use central vision like a spotlight (Moran, 1996) to focus directly on the areas that they feel are important. However, there are many second order themes produced in this study that are not directly linked to the area of fixation, for example in the hurdle steps the participant fixated on the torso, but suggested that were looking for foot placement on the board. This can be explained by two mechanisms. Firstly, it may be that the participants have a wide visual spotlight span from which they can extract information from. Alternatively, and perhaps more likely given the citations in other literature (Williams & Davids, 1998), the findings suggest that experts anchor their vision on a central area but use information from the periphery (Williams & Davids, 1998) to aid their judgments. This is consistent with other research suggesting that experts are able to utilise cues that are located around rather than in the area of the fixation (Williams & Davids, 1998). This finding suggests that novices need to use peripheral vision if they aim to become more adept at forming accurate judgments.

6.4.1 Conclusion

The visual data suggest that coaches and judges use selective attention in the first four phases of the vault. Specfically the coaches and judges fixated on the shoulders during the run up and on the torso during the hurdle step, first flight and second flight. However, the landing phase requires the ability to switch attention between the shoulders and torso. In addition, the participants noted three to four aspects of the vault they were interested in at each phase, suggesting that the participants used in this study anchored their vision primarily on one area (e.g., on the shoulders during the run-up) but were able to identify other demands of the run up (such as the speed of the arm pump and dynamics) suggesting that peripheral vision may be important for these experts participants. In addition, many of the second order themes reflected the judging criteria used by judges in gymnastics for example a straight body, height and distance in the second flight, suggesting that aspects of the criteria are held in LTM as a frame of reference which could direct the visual search patterns. Conversely, there were second order themes that were not thoroughly consistent with the judging criteria. This may be as a result of the coaches in the study not being familiar with the criteria, or it may be that these experts have expanded on their knowledge over the years and therefore identify good performance using other aspects beyond normal marking criteria.

The Effects of Perceptual Training on Visual Search Patterns and Accuracy of Judgments; A Group-Based Analysis

This chapter reports the findings of a study designed to examine the effects of perceptual training on visual search patterns and the accuracy of judgments for coaches and judges. This study is designed to meet aim four of the research project and the information gained from the study will be used to examine the effectiveness of the perceptual training videos developed from the data in study three.

This study combined with the data from study three has been accepted for the 12th ISSP World Congress of Sport Psychology, Marrakesh, 2009

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7.1 INTRODUCTION

Perceptual learning refers to the relatively long-lasting adaptation to an organism's perceptual system that improves its ability to respond to the environment (Goldstone, 1998). At a behavioural level, perceptual learning refers to improvements in complex perceptual-based skills as a result of training (Sowden, Davies & Roling, 2000). The advanced perceptual skills of elite athletes in different sports have served as a foundation for numerous experiments looking for an empirical basis for training programmes (Farrow & Abernethy, 2002; Farrow et al., 1998; Williams et al., 2002; 2003). From an applied perspective, the key issue is whether there are any potential training methods that can be employed to enhance the development of perceptual skill in sport (Williams & Ward, 2003).

Empirical evidence suggests that visual processing can be trained through the use of videos in specific sports (Williams et al., 2002; Williams et al., 2003). Traditional perceptual training methods attempt to closely replicate or simulate the perceptual conditions present in the real-world competitive setting (Jackson & Farrow, 2005). There are a number of mechanisms that underlie the effectiveness of perceptual training videos. Pertinent to this study are the orientation of visual attention, and development of knowledge regarding specific types of performance.

7.1.1 Orienting of visual attention

Skilled performance is only possible if attention is directed towards task relevant features (Abernethy, 2001; Janelle, Duley & Coombs, 2004). Posner (1980) suggests that attentional cues can be used in visual displays to direct the participant's attention towards certain features. Traditional perceptual training programmes have included "a large explicit component in which performers are directed to attend to specific visual cues, coupled with repeated exposure to exemplar video stimuli, usually depicting a high-level performer" (Jackson & Farrow, 2005, p.310). However, the exact design of the videos has not been well documented in the literature.

Three recent studies that have utilised previous research in order to elicit the important cues for performance include Abernethy et al. (1999), Williams et al. (2003) and Poulter et al. (2005). Such studies have found that this method of training (sometimes combined with biomechanical data; Abernethy et al., 1999; Poulter et al., 2005) has improved prediction of stroke depth and direction in novice squash players (Abernethy et al., 1999), eye movement behaviour of novice soccer players (Poulter et al., 2005) and the response time of experienced hockey players (Williams et al., 2003).

The underlying premise for these studies is that perceptual training through orienting visual attention can increase accuracy and speed of decisions. However, programmes that are developed based on visual cue data only, may not relate to what is actually perceived by the experts. Experts may use peripheral stimuli in relation to a focal point of gaze when controlling their behaviour (Williams et al., 1999). This seems logical given that the retinal periphery is highly adapted for perceiving information on movements (Milner & Goodale, 1995). Interestingly, much of the visual search research (e.g., Bard & Fleury, 1976; Ripoll et al., 1995; Savelsbergh et al., 2002; Ward et al., 2002; Williams & Davids, 1998) has identified times where performers did not anchor their vision on pre-defined specified areas of the display and consequently may have used peripheral vision to analyse the performance.

In addition, it seems that attention can be moved around the visual field without making distinctive eye movements to change point of fixation (Jonides, 1981; Sanders & Houtsman, 1985). Therefore foveal fixation data may not be detailed enough to produce informed perceptual training videos. Indeed, Williams and Davids (1997) highlight the need to combine eye movement registration techniques with parallel measures of information extraction when attempting to understand the perceptual strategies employed by performers. In addition, Williams et al. (1993) suggest that training programmes should include tasks that contribute towards the development of a comparable cognitive knowledge base on which visual search strategies may be based.

7.1.2 Development of knowledge base

Thomas, French and Humphries (1986) suggested that sport performance is a combination of cognitive knowledge and a player's ability to produce the sport skill(s) required. Research has consistently found that experts have superior contextual (sport-based) knowledge to novices (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981). Williams et al. (1999) suggest that more elaborate task-specific knowledge bases allow performers to interpret events encountered in circumstances similar to those previously experienced. These ‘knowledge structures’ direct players’ visual search strategies towards more pertinent areas of the display based on their expectations and the more effective processing of contextual information (e.g., pattern recognition, advance cue utilization – see section 2.3.1.3 for a review of these concepts). Moreno et al. (2002) found differences in visual search patterns of expert and novice judges, suggesting that the expert coaches and judges have different knowledge that guided their eyes to different areas of the display. Support for these ideas can also be found in study two of this thesis where expert and novice gymnastics coaches and judges produced significantly different visual search patterns.

The knowledge base of expert performers has typically been determined using verbal report data. Typically verbal report procedures require participants to articulate the area of the display that they consider to be important (Williams & Davids, 1997). Studies that have used verbal report data aimed at increasing the knowledge base of individuals include Mascarenhas et al. (2005) who investigated whether they could train decision making in Rugby Football Union (RFU) officials. Clips of tackles were verbally interpreted by Ed Morrison (at that time the number 1 ranked RFU referee). Mascarenhas et al. (2005) found no significant differences in accuracy of decisions based on their training videos, except in the lower level referees. However, this study did not use a placebo group, raising the possibility that the reported limited benefits were due to a familiarity effect. Such studies should therefore include a placebo group to account for this effect. In contrast, Grant and Williams (cited in Williams & Ward, 2003) found that after three two hour training sessions novice soccer players, who received instructional feedback in the form of important sources of information that underlie game reading skills, improved their accuracy of response to ‘freeze play’ situations compared to those who received no instructions. However, the control group did not get to see the same amount of footage as the perceptual training group suggesting that this might also be a result of a familiarity effect.

The mechanisms by which the perceptual training programmes alter performance have yet to be fully understood. However, the documented impact that such programmes have on visual search variables suggest that alterations in visual search may be one of the underlying mechanisms through which such programmes aid performance. Indeed, Adolphe et al. (1997) found that a six week visual attention training programme that included, amongst other things, video feedback of gaze behaviour, produced significant improvements in tracking onset, tracking duration, tracking offset, and gaze location. In addition a three year follow up of accuracy found that athletes who had received the visual attention training were significantly more accurate at performing than those that had not received training. In support, Harle and Vickers (2001) found that university basketball players who received quiet eye training over two seasons of league play improved significantly, pre to post, in experimental accuracy, quiet eye duration, and relative shot timing, compared to two control teams in season one. By the end of season two, the team that received the quiet eye training improved their free throw shooting accuracy by 22.62% to 76.66% which was greater than the control teams. Furthermore, Poulter et al. (2005) found that an implicit perceptual training programme (based over one session) did not change visual search behaviour (number of fixations and percentage viewing time) of non-sports players ($p>0.05$). However, the explicit training programme produced significant changes in allocation of viewing time from pre to post-test consistent with instructions given to the participants ($p<0.05$).

Given the differences between expert and novice visual search patterns (Goulet et al., 1989; Moran et al., 2002; Williams & Davids, 1998; Williams & Elliot, 1999; Williams et al., 1994; Study two of this thesis) and the effectiveness of perceptual training programmes on indicators of cognitive performance such as anticipation (Abernethy et al., 1999; Farrow et al., 1998; Hagemann et al., 2006; Williams et al., 2002) it seems logical that a perceptual training programme aimed at changing visual search may benefit other cognitive indicators of performance such as judgment formation. However, although interventions aimed at altering visual search have intuitive appeal (Jackson & Farrow, 2005), little research has been conducted in the area of judgment formation.

Therefore this study aims to evaluate the impact of perceptual training videos, using a between-groups factorial design with repeated measures. The impact of the perceptual training programme will be measured based on the 'experts' models of visual search produced in study three (see Tables 6.1 & 6.2). For example, the closer the participants become to the visual search values produced by the experts in study three (for example, seven fixations per vault) the lower the error value they will obtain. If a participant produces an error value of zero for number of fixations this would suggest that they have exactly replicated the experts' from study three's number of fixations (seven per vault). A control DVD using the same footage without any instructions will be used to ensure that any changes in visual search are as a result of a meaningful treatment effect rather than increased familiarity with the test situation (Williams & Grant, 1999), a factor that has been neglected by past research. This study will also include a retention stage to investigate the longer-term effects of such training videos on visual search, a factor that has not been investigated previously (Gorman & Farrow, 2009).

It would seem logical that novice participants would benefit from the perceptual training intervention given that the training DVD was formulated based on the empirical data showing that there were differences in expert and novice visual search from study two. Therefore this study aimed to investigate the impact of the perceptual training programme on the visual search patterns and accuracy of judgment of novice coaches and judges.

7.1.3 Hypotheses

As stated above error values will be calculated by comparing the values gained for each dependent variable (number of fixations, fixation duration, number of areas fixated, and outcome judgment) at each stage (baseline, post-test, and retention) to the experts' data from the experts' models presented in Tables 6.1 and 6.2.

1a) The perceptual training group will produce significantly less error for number of fixations at the post-test and retention stage than the control group.

1b) The perceptual training group will produce significantly less error for fixation duration at the post-test and retention stage than the control group.

1c) The perceptual training group will produce significantly less error for number of areas fixated at the post-test and retention stage than the control group.

1d) The perceptual training group will produce significantly less error for outcome judgment at the post-test and retention stage than the control group.

7.2 METHOD

7.2.1 Participants

Nine coaches and judges were recruited from British Gymnastics to participate in the study. However, two participants withdrew from the study and one participant's data was discarded due to data capture errors (see section 4.2.1 for an explanation of the data capture errors). Of the remaining six coaches and judges five were novices (three female, two male) based on their assistant club coach, club coach and club judge qualifications. The five coaches and judges had a mean age of 30.8±12.69 years, and 4.6±3.7 year's experience and formed the sample of novice judges used in this study.

The participants were divided between two conditions 1) experimental (n=3) and control (n=2). All participants provided informed consent prior to commencing the study (appendix 1) having read an information sheet (appendix 11). Ethical approval was gained from the University ethics committee.

7.2.2 Experimental Design.

Intervention studies lend themselves to being examined using a variety of methods. This experimental study employed a factorial design comparing the two groups (perceptual training vs. control) at three different points in time (baseline, post-test, and retention).

7.2.3 Task and design

The task examined the ability of participants to accurately judge a series of handspring vaults. Each of the data collection time points (baseline, six weeks, and retention) involved watching 14 handspring vaults, of which the same five vaults were analysed for visual search patterns and decision making accuracy. The same vaults were viewed by each participant to ensure equivalent level of difficultly (Poulter et al., 2005).

7.2.3.1Test film – eye tracking

The videotape was created from footage of handspring vaults collected at a gymnastics club training session. Handspring vaults were recorded using a Canon video camera (model NV7001), mounted on a tripod positioned perpendicular to the vault, representing where a judge would be sat in competition. All handsprings were produced by three intermediate gymnasts. This 'own point of view' recording provides minimum distortion of the complexity and dynamics of naturalistic environments (Omodei et al., 1998) and therefore maximises physical fidelity (Lintern et al., 1989). Increases in fidelity are said to increase transfer of learning (Alessi, 1988). 30 videotaped gymnastic vaults were initially collected, of which 14 were used in the study. The vaults were then edited using ADOBE premiere, which allowed the researcher to re-arrange the order for each participant. ADOBE premiere also allowed the researcher to edit in the marking criteria between each vault which was paused during the testing phase for as long as each participant needed. Each clip lasted between four and six seconds and showed one handspring vault. Of the 14 edited vaults, five were used for analysis in the study. The other nine were used to ensure that the test vaults were disguised within the test-film. All vaults were handsprings, representing what club level judges might see in competition.

Video footage of the vaults was back projected onto a large screen (6ft × 5ft). Participants were seated approximately three metres from the screen. Participants were required to state their responses verbally, and these were recorded by the researcher.

7.2.3.2 Eye movement recording

Eye movements were recorded using an eye tracking system (ASL Series 5000) sampling at a rate of 50 Hz that recorded gaze direction with an accuracy of ±.5°. Eye calibration was conducted with each participant immediately prior to the start of the experiment using a nine-point reference grid projected onto the screen (see Figure 3.6). For the purpose of analysis, data from the eye tracker were superimposed onto the video of the vaults using a crosshair to indicate point-of-gaze.

7.2.4 Procedure

Participants were tested individually at a University laboratory. One week prior to testing each participant was sent an information sheet (appendix 11). Participants were asked to familiarise themselves with this.

Upon arrival, standardised introductory comments were provided pertaining to the general purpose of the study, the use of data and issues regarding confidentiality and anonymity. Specifically, participants were told that they would view clips of gymnasts performing a handspring vault from a judge's perspective and that their task was to assign it a score and say aloud the score to the researcher. Each participant was randomly assigned to either the experimental or control condition. All participants then completed the baseline test. All participants were given information regarding the frequency with which to watch the DVDs (twice a week), and more information about the length of the intervention which was six weeks, based upon the time-periods used in the perceptual training of gaze behaviour study by Adolphe et al. (1997). The manipulation check took the form of a diary that had two time slots each week where participants could record when they watched the DVD. Participants were also informed about the retention stage in week ten. A retention stage was used to determine whether training improvements were relatively permanent or as a result of transient changes in performance, a factor that has not been considered in previous research (Williams & Grant, 1999). When all questions had been answered participants gave informed consent both verbally and in writing (appendix 1). Once consent had been gained each participant completed a demographic questionnaire relating to judging experience, gender, and age.

7.2.4.1 Testing procedures

Participants were seated and the ASL 501 eye tracker fitted. Prior to commencement of the test film participants were reminded that they were to view each vault and assign a score to the action. They were also informed that there was time between each vault to view the criteria and assign the score. The availability of the marking criteria at any time aimed to avoid the issues that novice judges have when trying to recall information about symbol code and criteria (Ste-Marie, 1999). The assigned score was noted on a results sheet by the researcher. Once it was clear that all instructions had been understood testing commenced. During testing the participants were not given information regarding the nature of the performers to avoid any expectation bias (Ansorge et al., 1978). The gymnasts were not known to the participants to prevent reputation effects (Findlay & Ste-Marie, 2004). No feedback was given regarding their judging of each vault to reduce the occurrence of the Hawthorne effect (Thomas et al., 2005). Upon completion of data gathering, each participant was debriefed during which questions focused upon how they felt about the testing protocol and comfort with the eye tracking headgear. No discussion took place regarding the vaults and their scoring performances to reduce biasing within future data collections. After completion of the testing, the researcher verbally checked that the participants were aware of how often they needed to view the DVD, gave the participants the reminder diary for viewing the DVD, and booked a time for them to return in six weeks.

At six and ten weeks further data were collected, each time the vaults were viewed in a randomised order to reduce order effects and memory influenced bias (Ste-Marie & Valiquette, 1996; Ste-Marie, Valiquette & Taylor, 2001). The participants were tested prior to the intervention being introduced (baseline), post-intervention at six weeks (post-test), and four weeks after the intervention had been withdrawn at ten weeks (retention). After the retention stage all participants were required to take part in a brief social validation interview where participants were invited to provide subjective comments on the perceived influences of the interventions received.

7.2.4.2 Perceptual training condition

Each DVD consisted of ten handspring vaults. First a vault was shown in real time, with the light circles tracking the areas of fixation by the experts found in study three (run up = shoulders, hurdle step = torso, first flight = torso, second flight = torso, landing = shoulders and torso as shown in Figures 7.1 to 7.4). The second run through of the vault had freeze frame parts at each of the five stages, where the second order themes identified by the expert participants in study three were presented on the screen (see Figures 7.5 and 7.6).

At the beginning of the DVD participants were explicitly reminded to watch the DVD twice a week. The perceptual training DVD had explicit instructions that stated that the light circles that were presented on the screen throughout the entire vault highlight relevant parts of the body related to where experts were looking when viewing the vault (see Figures 7.1 to 7.4).

Figure 7.1: Shoulders highlighted

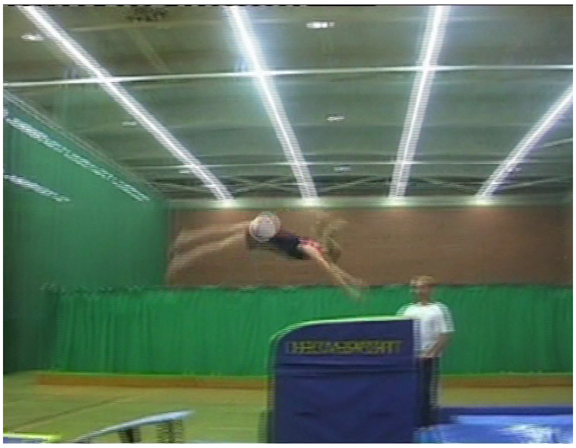

Figure 7.2: Torso highlighted

Figure 7.3: Torso highlighted

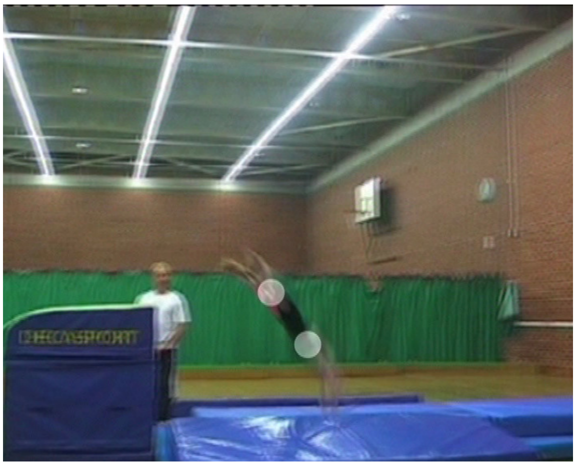

Figure 7.2: Torso and shoulders highlighted

The perceptual training DVD also had explicit instructions that explained that the written words that they would see on the screen were related to what experts were looking for at the specific phases of the vault (see Figures 7.5 and 7.6).

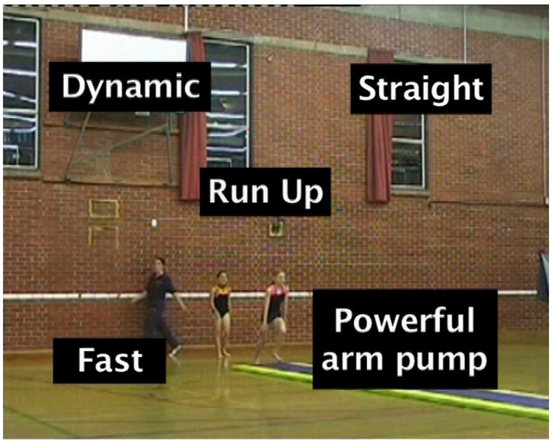

Figure 7.5: Declarative knowledge for run up

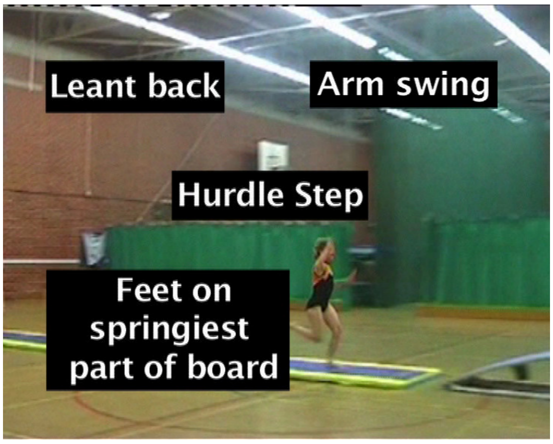

Figure 7.6: Declarative knowledge for hurdle step

An explicit component was included in the video as Poulter et al. (2005) found that explicit instruction resulted in changes in eye movement behaviour. The participants were not given information relating to the values of each vault ensuring that the training video also utilised a guided discovery approach. A guided discovery component was included because Smeeton et al. (2005) found that participants that underwent a guided discovery based intervention produced faster decision making under anxiety-provoking conditions.

7.2.4.3 Control condition

Participants in the control condition were each given a DVD consisting of ten handspring vaults. Each handspring vault was shown twice in real time, to ensure that vault familiarity (i.e., number of times viewing each vault) was controlled. The DVD had no information relating to gaze behaviour or knowledge (see Figures 7.7 to 7.10).

Figure 7.7: run up (no information)

Figure 7.8: first flight (no information)

Figure 7.9: second flight
(no information)

Figure 7.10: landing (no information)

7.2.5 Data Analysis

To assess the impact of the perceptual training programme the data were analysed using three methods. Firstly, a 2 (control vs. perceptual training) x 3 (intervention phase) analyses of variance (ANOVA) with repeated measures (McPherson & MacMahon, 2008) was conducted to analyse differences between the novices in the perceptual training and control groups, for each of the four dependent variables. Error at each of the three time points was calculated in relation to the expert data from study three of this thesis using a temporal based analysis, based on the five stages of the vault for the participants in the perceptual training group and control group. This enabled an understanding of how the error changed throughout the intervention. Finally, using the absolute error values, percentage change (Atkinson & Neville, 2001) of the error values was assessed for the participants in the perceptual training and control groups to show the degree to which the error changed.

7.2.5.1 ANOVA Calculations

A 2 (control vs. perceptual training) x 3 (intervention phase) ANOVA with repeated measures on the last factor was conducted to compare between the perceptual training and control group for each dependent variable. Where significant effects were revealed follow up planned comparison t-tests were conducted (Pallant, 2005). Partial eta squared (η^2) effect sizes were also computed. In line with the recommendations of Clark-Carter (1997), effect sizes of between .001 and .058 were classified as small, effect sizes of between .059 and .137 classified as medium, and effect sizes over .138 were classified as large. There are limitations to using inferential statistics with low participant numbers. Therefore interpretation of the inferential statistics must be considered with caution given that autocorrelation may be present within the data set which will affect the power of the study (Todman & Dugard, 2001). Therefore generalisations beyond the group which is being tested is problematic.

7.2.5.2 Changes in error values based on three time points

To proceed further with this analysis, temporal based error values for each of the five stages of the vault (discussed in section 6.2.5) were calculated for each of the visual search variables. This indicated whether the groups distributed their visual fixation in a manner that was more analogous to the experts' data from study three. For example, the perceptual training group might produce 6 fixations at baseline, post-test and retention, but by the retention they may be spread over the five phases more analogous to the experts rather than being all in one phase. To obtain the error data for the three visual search variables the following calculation was used

Error (run up, hurdle step, first flight, second flight, landing)

= Actual value at each phase – Experts value at each phase

The experts values were obtained from the expert model presented in Table 6.2. Once the error had been calculated for each phase of each vault, negative values were then converted to positive values to obtain absolute error. Using the absolute error values the mean absolute error was taken for each vault. The mean absolute error for each of the five vaults was then calculated for each of the three time points (baseline, post-test, retention) for each group.

To obtain error data for the outcome judgment, error values for each of the five vaults were calculated. This indicated whether the groups gave outcome judgments that were more analogous to the experts' data from study three. Error values were calculated using the following formula.

Error (for each vault)
= Actual value given for each vault – Experts value for each vault

Once the error had been calculated for each vault, negative values were then converted to positive values to obtain absolute error. The mean absolute error for each of the five vaults was then calculated for each of the three time points (baseline, post-test, retention). Percentage change data was calculated from the following equation.

$$\frac{V_2 - V_1}{V_1} \text{ X } 100 = \text{Percentage change}$$

To calculate the percentage change from baseline to post-test V_1 was equal to the group baseline value and V_2 was equal to the group post-test value.
For the baseline to the retention stage V_1 was equal to the group baseline value and V_2 was equal to the group retention value.
For the post-test to the retention stage V_1 was equal to the group post-test value and V_2 was equal to the group retention value.

7.3 RESULTS

7.3.1 Number of fixations

A 2 (control vs. perceptual training) x 3 (intervention phase) ANOVA with repeated measures on the last factor showed that there was a significant group x time interaction, $F(2,6) = 12.57$, $p = .01$, effect size $\eta^2 = .81$. Follow up t-tests (control v perceptual training group) revealed no significant differences for the baseline number of fixation values, $t(3) = 1.53$, $p = 2.23$, and post-test number of fixation values between the perceptual training and control group, $t(3) = -2.54$, $p = .09$. However, there was a significant difference for the retention number of fixation values ($t(3) = -3.22$, $p = .05$) between the perceptual training and control group. The perceptual training group produced significantly less error (mean = 0.27 ± 0.12) than the control group (mean = 0.56 ± 0.00) at the retention phase (see Table 7.1).

Table 7.1: Mean and SD for number of fixations for the perceptual training and control group.

Mean [SD]	Baseline	Post-test	Retention
Perceptual training group	0.65 [0.06]	0.28 [0.7]	0.27 [0.12]
Control group	0.58 [0.03]	0.48 [0.11]	0.56 [0.00]

7.3.1.1 Changes in Error

To understand in more detail whether the error changes were towards the expert's values, absolute error was calculated for the participants who underwent the perceptual training programme and the control group.

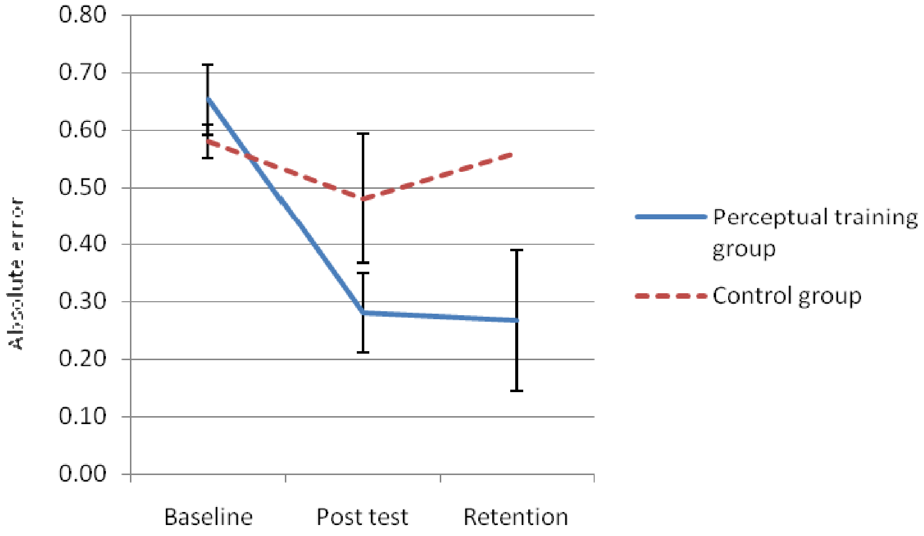

Figure 7.11: Absolute error values for number of fixations for the perceptual training and control groups.

7.3.1.1.1 Baseline to Post-test

Figure 7.11 shoes that the perceptual training group decreased in error for the number of fixations from the baseline (mean = 0.65) to the post-test (mean = 0.28) by 57.1%. The control group also showed a decrease (from M = 0.58 at baseline to M = 0.48 at the post-test) in error but not to the same extent as the perceptual training group (17.2%).

7.3.1.1.2 Baseline to Retention

The perceptual training group decreased in error for the number of fixations from the baseline (mean = 0.65) to the retention test (mean = 0.27) by 59.2%. The control groups error values increased by 3.4% from Mean = 0.58 at baseline to Mean = 0.56 at the retention stage.

7.3.1.1.3 Post-test to Retention

The perceptual training group decreased in error for the number of fixations from the post- (mean = 0.28) to retention test (mean = 0.27) by 4.8%. The control group showed increased error from the post-test (mean = 0.48) to the retention test (mean = 0.56) by 16.7%.

7.3.2 Fixation duration

A 2 (control vs. perceptual training) x 3 (intervention phase) ANOVA with repeated measures on the last factor showed that there was a significant group x time interaction, $F(2,6) = 7.49$, $p = .02$, effect size $\eta^2 = .71$. Follow up t-tests (control v perceptual training group) revealed no significant differences for the baseline fixation duration values, $t(3) = 0.81$, $p = .48$, and the retention fixation duration values, $t(3) = -2.84$, $p = .07$, between the perceptual training and control group. However, there was a significant difference for the post-test fixation duration values between the perceptual training and control group, $t(3) = -6.56$, $p = .01$. The perceptual training group produced significantly lower fixation duration error (mean = 54.36 ± 5.85) than the control group (mean = 96.35 ± 8.89) at the post-test (see Table 7.2).

Table 7.2: Mean and SD for fixation duration for the perceptual training and control group.

Mean [SD]	Baseline	Post-test	Retention
Perceptual training group (ms)	90.59 [15.69]	54.36 [5.85]	49.23 [14.55]
Control group (ms)	79.27 [14.67]	96.35 [8.89]	81.31 [5.95]

7.3.2.1 Changes in error

To understand whether the error changes were towards the experts' values, absolute error was calculated.

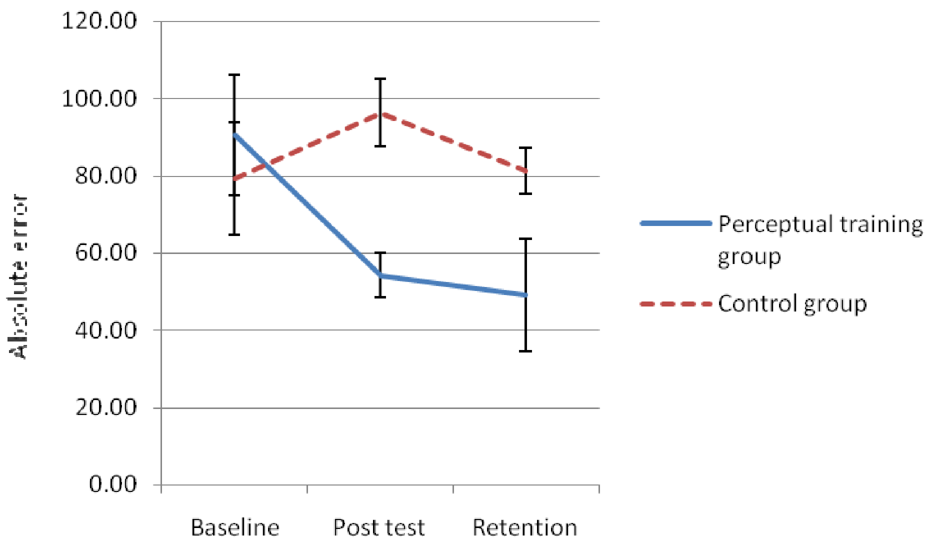

Figure 7.12: Absolute error values for fixation duration for the perceptual training and control groups.

7.3.2.1.1 Baseline to Post-test

The perceptual training group decreased in error for fixation duration from the baseline (mean = 90.59ms) to the post-test (mean = 54.36ms) by 40.0%. The control group showed increased error from the baseline (mean = 79.27ms) to the post-test (mean = 96.35ms) by 21.6%.

7.3.2.1.2 Baseline to Retention

The perceptual training group decreased in error for fixation duration from the baseline (mean = 90.59ms) to the retention stage (mean = 49.24ms) by 45.6%. The control group showed increased error from the baseline (mean = 79.27ms) to the retention stage (mean = 81.31ms) by 2.6%.

7.3.2.1.3 Post-test to Retention

The perceptual training group decreased in error for fixation duration from the post-test (mean = 54.36ms) to the retention stage (mean = 49.24ms) by 9.4%. The control group decreased in error for fixation duration from the post-test (mean = 96.35ms) to the retention stage (mean = 81.31ms) by 15.6%.

7.3.3 Number of areas fixated

A 2 (control vs. perceptual training) x 3 (intervention phase) ANOVA with repeated measures on the last factor showed that there was a significant group x time interaction, $F(2,6) = 6.01$, $p = .04$, effect size $\eta^2 = .67$. However, follow up t-tests (control v perceptual training group) revealed no significant differences for the baseline number of areas fixated values, $t(3) = 1.34$, $p = .27$, post-test number of areas fixated values, $t(3) = -2.36$, $p = .09$, and the retention number of areas fixated values, $t(3) = -2.76$, $p = .07$, between the perceptual training and control group (see Table 7.3).

Table 7.3: Mean and SD for number of areas fixated for the perceptual training and control group.

Mean [SD]	Baseline	Post-test	Retention
Perceptual training group (ms)	0.60 [0.07]	0.36 [0.20]	0.23 [0.05]
Control group (ms)	0.52 [0.06]	0.64 [0.11]	0.52 [0.23]

7.3.3.1 Changes in error

To understand whether the error changes were towards the experts' values, absolute error was calculated.

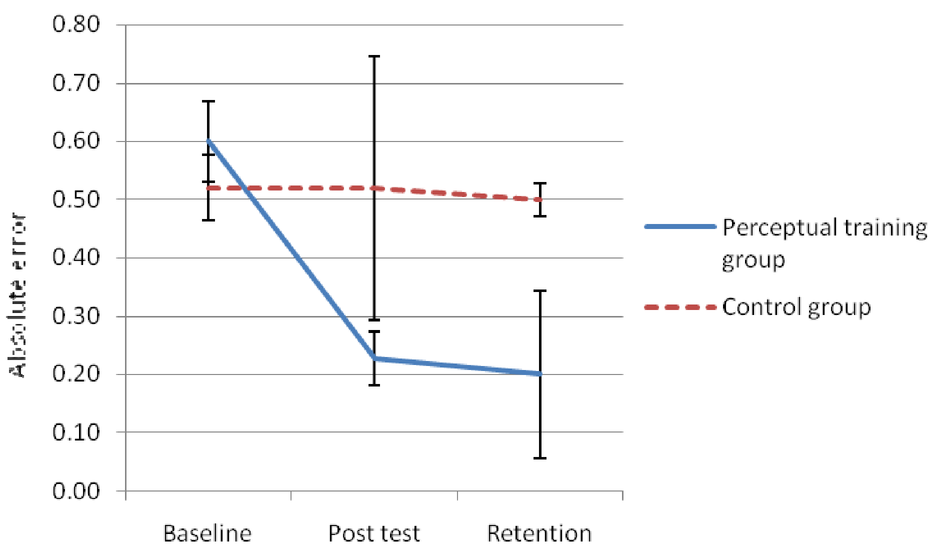

Figure 7.13: Absolute error values for number of areas fixated for the perceptual training and control groups.

7.3.3.1.1 Baseline to Post-test

The perceptual training group decreased in error for the number of areas fixated from the baseline (mean = 0.60) to the post-test (0.23) by 61.6%. The control group showed no change in error.

7.3.3.1.2 Baseline to Retention

The perceptual training group decreased in error for the number of areas fixated from the baseline (mean = 0.60) to the retention stage (mean = 0.20) by 66.7%. The control group decreased in error for the number of areas fixated from the baseline (mean = 0.52) to the retention stage (mean = 0.50) 3.8%.

7.3.3.1.3 Post-test to Retention

The perceptual training group showed slight decreases in error for number of areas fixated from the post-test (mean = 0.23) to the retention stage (mean = 0.20) by 11.8%. The control group showed slight decreases in error for number of areas fixated from the post-test (mean = 0.52) to the retention stage (mean = 0.50) 3.8%.

7.3.4 Outcome judgment

A 2 (control vs. perceptual training) x 3 (intervention phase) ANOVA with repeated measures on the last factor showed that there was no significant group x time interaction, $F(2,6) = 4.46$, $p = .18$, effect size $\eta^2 = .81$ (see Table 7.4) for outcome judgment.

Table 7.4: Mean and SD for outcome judgment for the perceptual training and control group.

Mean [SD]	Baseline	Post-test	Retention
Perceptual training group (ms)	1.15 [0.39]	0.76 [0.50]	0.71 [0.52]
Control group (ms)	1.49 [0.35]	1.71 [0.38]	1.29 [0.64]

7.3.4.1 Changes in error

To understand in greater detail whether the error changes were towards the experts' values, absolute error (per vault) was calculated. In addition to this, percentage change data is presented to represent the changes in error.

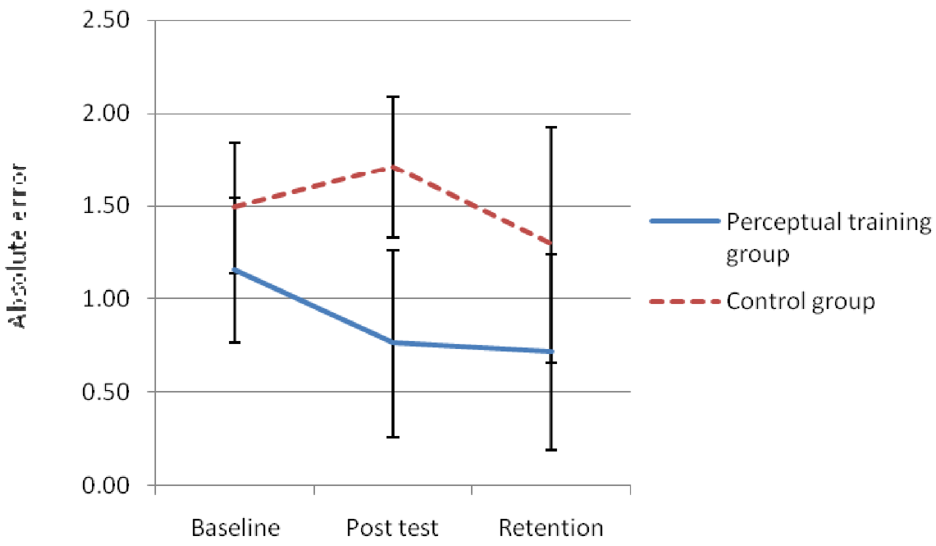

Figure 7.14: Absolute error values for the outcome judgment for the perceptual training and control groups.

7.3.4.1.1 Baseline to Post-test

The perceptual training group decreased in error for the outcome judgment from the baseline (mean = 1.15) to the post-test (mean = 0.76) by 34.1%. The control group showed increased error from the baseline (mean = 1.49) to the post-test (mean = 1.71) by 14.8%.

7.3.4.1.2 Baseline to Retention

The perceptual training group showed slight decreases in error for the outcome judgment from the baseline (mean = 1.15) to the retention stage (mean = 0.71) by 38.2%. The control group showed slight decreases in error for the outcome judgment from the baseline (mean = 1.49) to the retention stage (mean = 1.29) by 13.4%.

7.3.4.1.1 Post-test to Retention

The perceptual training group showed slight decreases in error for the outcome judgment from the post-test (mean = 0.76) to the retention stage (mean = 0.71) by 6.1%. The control group showed decreases in error for the outcome judgment from the post-test (mean = 1.71) to the retention stage (mean = 1.29) by 24.6%.

7.4 DISCUSSION

To establish the effectiveness of a perceptual training programme Hodges, Starkes and MacMahon (2006) and Ward et al. (2008) identified three central conditions. First, an expert protocol of visual attention must be developed from those that exhibit control over the allocation of attention during highly accurate performance of a skill. This was developed from the expert data collected in study three. Second, participants must be identified that have difficulty in fulfilling this potential. From study two it was obvious that novice coaches and judges have difficulty in this area. Finally, having received the perceptual training programme the participants must overcome the difficulties in the real world and do their job more accurately and this was the central test for this study. Specifically, this study focused on the relative effects of a perceptual training programme and a control condition on both outcome judgment and eye movement behaviour of novice coaches and judges. To understand the impacts of the intervention the hypotheses will be addressed.

The perceptual training programme had varied effects upon the four dependent variables (number of fixations, fixation duration, number of areas fixated, and outcome judgment). The inferential analysis showed that significant differences in the numbers of fixations were only evident at the retention stage with the perceptual training group producing significantly less error than the control group. The planned comparisons failed to reach significance at the post-test stage, perhaps due to low participant numbers and the high standard deviations achieved (see Table 7.1). However, the descriptive error analyses show that changes took place throughout the intervention. This was particularly evident when examining the changes in the number of fixations per vault, where the participants in the perceptual training group decreased their error in the number of fixations from baseline at both the post-test and retention stages.

The reduction in error could be explained through developments in knowledge as a result of the DVD's which could have lead to adjustments of their cognitive maps (Treisman & Gelade, 1980). These changes could have subsequently altered the frequency of the fixations used to search the display. This suggests that a perceptual training programme aimed at modifying both visual search patterns and declarative knowledge is effective at enabling coaches and judges to produce fixation numbers that are similar to experts.

The numbers of fixation findings are particularly important given the large volume of research that has suggested that expert and novices produced significantly different number of fixations (e.g., Bard & Fleury, 1976; Helsen & Pauwels, 1992,1993; Mann et al., 2007; Moreno et al*.,* 2002; Ripoll et al., 1995; Savelsbergh et al*.,* 2002; Singer et al*.,* 1996; Vickers, 1996a, b). The findings of the current study suggests that if the number of fixations hinders performance of novice coaches and judges then a perceptual training programme based on experts declarative knowledge and eye-tracking patterns may be an effective method of training them.

Changes in fixation duration were also evident after the perceptual training programme. The inferential analysis showed that significant differences were only evident at the post-test stage with the perceptual training group producing significantly less error. This suggests that a perceptual training programme aimed at altering visual search patterns and declarative knowledge is effective at enhancing fixation duration, however the impact may not be long-term. Again, the failure to reach significance at the retention stage may be explained by the low participant numbers and the high standard deviations achieved (see Table 7.2). This is important given the consistent findings that experts and novices produced different fixation durations (Helsen & Pauwels, 1992, 1993; Moreno et al., 2002; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996; Vickers, 1996a, b). In addition the perceptual training group further reduced their error from post-test to retention showing that the impact of the perceptual training programme is retained. However, the control group mean also changed at the retention stage resulting in no statistical difference. These results suggest that the perceptual training programme was effective in modifying the visual fixation duration of the novice coaches and judges. As previously stated, the intervention may have developed their knowledge and cognitive maps (Treisman & Gelade, 1980), which could have subsequently changed the duration of the fixations used to extract information about the display. This finding suggests that if fixation duration hinders performances of novices then a perceptual training programme may be an appropriate means of training them.

The training programme was also quite effective at altering the number of areas fixated for the novice participants. The ANOVA revealed a significant interaction effect. However, the planned t-test could not locate where the difference(s) took place. The mean values per vault show that the participants decreased their error for the number of areas fixated as a result of the training programme from baseline to post-test and from baseline to retention. These results suggest that the training DVD was effective in altering elements of visual search for the novice participants which may have been caused by changes to the perceived pertinence of selected areas as a result of the emphasis of the training DVD guiding attention to selected areas.

The perceptual training programme also aided the novice participants in becoming analogous to the experts' outcome judgment scores. However, ANOVA failed to reach significance, perhaps due to low participant numbers and high standard deviations (see Table 7.4). The participants decreased their error in outcome judgment from baseline to the post-test as shown by the absolute error values. Interestingly, at the retention stage, the participants had furthered their reduction in error of outcome judgment. These changes in outcome judgment may have been caused by the re-distribution of the fixations throughout the handspring vault. For example, the attention to the gymnast's shoulders in the run-up may have enhanced their ability to anticipate the quality of the imminent movement. A relationship between the utilisation of early cues and enhanced judgments was found by Ste-Marie (1999).

Alternatively, given the nature of the training video, the improvements in outcome judgment can also be explained by the novices newly developed ability to selectively attend (Norman, 1968). Indeed, the perceptual training DVD used in this study was developed using only information that was frequently cited by most experts. Therefore the cues that were highlighted were limited to one to two areas per vault which could have encouraged the novices to rely only on the information given, rather than searching as much as possible. This suggests that the development of selective attention is an important factor for novice coaches and judges.

The improvements in outcome judgment can also be explained through the mechanism of enhanced signal detection (Swets, 1964). The highlighted areas of the body in the perceptual training DVD could have enhanced the intensity of the visual signal which should have reduced the surrounding perceptual noise. Therefore the novice coaches and judges could have identified the cues quickly, and therefore had more time to process them in order to select the most appropriate outcome judgment.

Whilst these results must be treated with caution, given the low participant numbers, they do support alterations in visual fixations as potential mechanisms for enhancing the development of judgment formation for novice participants. This is supported by research that has found that perceptual training has an effect on visual search variables (Harle & Vickers, 2001) and decision making (Caserta et al., 2007). The outcome judgment findings show that a perceptual training programme aimed at modifying both visual search patterns and declarative knowledge is effective at enabling novice coaches and judges to produce outcome judgments that are similar to experts. This is perhaps the most interesting finding given that the most significant role of judges and coaches involves their ability to judge the quality of a performance. This finding suggests that if novices want to accelerate and become more like experts in terms of their decision making then a perceptual training programme may be an effective method of training them.

A striking feature of these data is the evidence of a retention effect by the novice participants who underwent the six week perceptual training programme. This is the first perceptual training study to include a retention stage when measuring visual search variables, and despite the limited number of participants involved, the error by phase analyses suggest that training effects continued and, perhaps more remarkably, improved within a four week period after the training programme was withdrawn. This may be a result of the newly acquired knowledge being used in the real world whilst coaching and judging and thus the cognitive map is developed and strengthened. This has significant implications for the use of training programmes that include both explicit instructions and guided discovery elements early in coaches and judges careers, which may have long term benefits for coaches and judges.

To further understand the impacts of perceptual training, this study employed a control condition where participants observed the same amount of vaults, addressing previous concerns in the literature made by Williams and Ward (2003) and Gorman and Farrow (2009) regarding the implications of test familiarity. The error values for the novice participants that watched the control DVD were significantly higher than the participants that undertook the perceptual training programme at specific intervention time points. Therefore, the changes in outcome judgment data and visual search variables produced by the perceptual training programme seems to be due to the perceptual training programme rather than content familiarity given that the novices in the control condition watched the same amount of vaults and did not make changes in their visual search or outcome judgments to the same extent. It is also important to note that reducing the data to group means and standard deviations can mask the true effect of the intervention (Chow, Davids, Button & Koh, 2008) and therefore future studies should focus on analysing data utilising a case by case design.

In addition to the quantitative data, this study also employed a social validation interview for each participant (see appendix 12 for an example) following the guidelines of Thelwell and Maynard (2003). Questions were asked regarding “How useful do you think the intervention was?” “Would you recommend it to others?” and “What changes would you make to the intervention?” When asked how useful the intervention was the trend suggested that the intervention was useful. The novice participants that took part in the perceptual training video reported that

‘*now ... I’m picking up things a lot better’*,’ *you do tend to start looking at things in a different light and actually picking out significant areas where you would want to look at thing probably in more detail than you have necessarily before*’ and ‘*I figured that that was where to look to see .... where you’re going to get the most information from about the quality of the performances*’

The findings from the social validation interview suggest that the training methods used were effective from the subjective view point of the novice participants involved. Interestingly, one novice in the control condition suggested that their video was also useful implying that repeatedly being exposed to the same content might also help novice coaches and judges. Interestingly, all three of the novices in the perceptual training group suggested that they felt that other novice coaches and judges would benefit from the perceptual training intervention. This indicates that they felt that the benefits of the training programme would extend beyond themselves. There were no recommendations made in the social validation interviews for improving the perceptual training DVD's from the novice coaches and judges who underwent the perceptual training programme.

7.4.1 Implications

In order to further the current literature regarding perceptual training in sport, the perceptual training DVD utilised in this study was developed based on the trends of visual search patterns and knowledge base of eight experts. This was signified by placing light circles around the areas of importance, combined with freeze frames showing what the experts were looking for. There have been very few studies that have aimed to assess the impact of training both visual search and declarative knowledge and this study adds to the reported effectiveness of this particular training technique for novice coach and judge populations.

It appears that a combination of both declarative knowledge in the form of written statements and visual search patterns through highlighting areas of the body does appear to be useful for training novices' judgments, but the relative contributions of declarative knowledge and visual search in the training of judgment formation are not known. An alternative method would have been to test training videos that contain only knowledge and only visual search. However, positive findings from the perceptual training and anticipation literature (McMorris & Hauxwell, 1997; Williams & Burwitz, 1993) indicate that a combination is the most effective approach. Additionally, it would be interesting to investigate whether the knowledge base of the participants changed throughout this study. The changes in visual search, based on top-down processing, would suggest that the novices have undergone changes in their knowledge base, but the extent to which this has happened would need to be established using interviews.

Whilst this study advocates the use of perceptual training programme for training novice coaches and judges, these results must be interpreted with caution. The beneficial impact of the training programme on judgment formation may have been influenced by the coaching and judging that they had completed in between the pre and post tests, although it was ensured that the participants had not undergone any formalised training. In addition, the participants in the control condition did not make changes to the same extent.

7.4.2 Conclusion

To conclude, this study suggested that the perceptual training programme was effective at altering key components of visual search patterns and outcome judgments of novice coaches and judges in gymnastics at both the post-test and retention stage. The participants who underwent the perceptual training programme made changes to their visual search and outcome judgments towards to the expert model (developed from the study three data from this thesis). The participants who did not undergo the perceptual training programme made minor changes to their visual search patterns and outcome judgments, but these were not to the same extent as the participants that underwent the perceptual training programme.

The Effects of Perceptual Training on Visual Search Patterns and Accuracy of Judgments: A series of four case studies,

This chapter reports the findings of a study designed to examine the individual effects of perceptual training on visual search patterns and the accuracy of judgments for novice and expert coaches and judges. This study is designed to meet aim four of the research project and the information gained from the study will be used to examine the impact of the perceptual training videos developed from the data in study three.

This study combined with the data from study three has been accepted for the 12th ISSP World Congress of Sport Psychology, Marrakesh, 2009

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8.1 INTRODUCTION

This study aimed to examine the individual participant's changes that led to the group changes examined in chapter seven. To achieve this, the three participants that underwent the perceptual training programme will be considered in isolation as individual case studies. Further to the impacts of perceptual training on novice level participants, higher level performers have also been documented to benefit from a perceptual training programme. For example, Caserta et al. (2007) found that a perceptual training programme enhanced the response accuracy, response speed and decision making of tennis players that had a National Tennis Ranking of 3.17 (where one is novice and seven is tour player). Therefore single-case data from one expert will be also explored in a case study design.

Intervention studies lend themselves to being examined using a variety of methods. However, Franck (1986) suggests that "nomothetic science can never escape the individual" (p.24) and that designs should therefore investigate responses made by individuals rather than groups. Therefore following the factorial design presented in chapter seven, a series of four single case studies are presented based upon descriptive analyses.

The aim of a case study is not to determine unequivocally if an intervention is positively working but to provide compelling support for the use of a specific intervention (Strean, 1998). Therefore, given the lack of research investigating the impact of perceptual training on visual search, case studies may be useful in providing support for the mechanisms through which perceptual training may enhance performance. Case studies involve a non-experimental approach to evaluation that provide a holistic evaluative picture (Anderson, Miles, Mahoney & Robinson, 2002) and allow for the detection of small but consistent individual effects that might be masked in a group design (Bryan, 1987). Given the lack of significant differences based on the inferential statistics employed in study four for specific dependent variables, case study approaches were adopted to understand the impact of the intervention on the individual coaches and judges. A case study design is "a strategy for doing research (including evaluation) which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence" (Robson, 1993, p.146). The case study approach typically involves collecting data in the baseline period and, at least, again once the treatment has been implemented (Anderson et al., 2002). If there is an improvement in the data when the intervention has been introduced, confidence increases that the intervention is responsible for the change (Anderson et al., 2002). Confidence in case studies can be developed by assessing multiple dependent measures repeatedly, such as during intervention, prior to the intervention and after a retention phase and triangulating evidence, replicating the results across cases (Smith, 1988) and therefore this study has investigated multiple visual search related variables across four participants.

A case study approach to evaluation cannot prove that an intervention has caused any psycho-behavioural changes but it can provide evidence supporting whether the intervention is associated to some degree with improvement in the real world environment (Strean, 1998). Through the evaluation of multiple dependent variables, collecting both qualitative data through the form of social validation interviews and quantitative data through the measurement of the number of fixations, fixation duration, numbers of areas fixated and outcome judgment, a case study can provide a holistic picture of the intervention that can be used to document effectiveness and provide rich information that can be used to facilitate perceptual training intervention improvement. The value of a case study approach to evaluation has been previously recognized in clinical psychology (Persens, 1991), educational psychology (Cherry, 1998), and applied sport psychology (Smith, 1988; Strean, 1998).

8.1.1 Hypotheses

1a) Participants will produce lower mean error across vaults (outside the natural range of variation), and lower error by phase for the number of fixations at the during, post-test and retention stage compared to their baseline values, and at the retention stage compared to the post-test values.

1b) Participants will produce lower mean error across vaults (outside the natural range of variation), and lower error by phase for fixation duration at the during, post-test and retention stage compared to their baseline values, and at the retention stage compared to the post-test values.

1c) Participants will produce lower mean error across vaults (outside the natural range of variation), and lower error by phase for the number of areas fixated at the during, post-test and retention stage compared to their baseline values, and at the retention stage compared to the post-test values.

1d) Participants will produce lower error for the outcome judgment at the during, post-test and retention stage compared to their baseline values, and at the retention stage compared to the post-test values.

8.2 METHOD

8.2.1 Participants

Nine coaches and judges were recruited from British Gymnastics to participate in the study. However, two participants withdrew from the study and one participant's data was discarded due to data capture errors (see section 4.2.1 for an explanation of the data capture errors). Of the remaining six coaches and judges, four underwent the perceptual training programme. The novice coaches and judges (n = 3) had a mean age of 35.0±16.0 years, and 3.0±2.0 year's experience. The expert judge (n = 1) was 59 years old, and had 20 years of experience.

The participants considered in these case studies had all undergone the perceptual training programme. All participants provided informed consent prior to commencing the study (appendix 1) having read an information sheet (appendix 11). Ethical approval was gained from the University ethics committee.

8.2.2 Procedure

This study utilised the same methods as study four, however the control group has not been included in the case study analyses. In addition, a fourth data point was added three weeks into the intervention to understand the idiosyncratic impacts of the intervention on the individual participants.

8.2.3 Data Analysis

8.2.3.1 Changes in mean data across the four time points

To calculate changes in each individual's means for each of the dependent variables their values were compared with the expert mean data from study three of this thesis. The mean number of fixations for the experts (identified in study three of this thesis, Table 6.1) was 7, mean duration was 190.15ms, and mean number of areas fixated was 3. Therefore if a participant produced four fixations per vault at baseline, 4.6 at post-test and 5.3 at retention this would suggest that the participant had made successful changes towards the experts' data of seven fixations, consequently indicating an effective perceptual training programme.

However, study one in this thesis indicated that each visual search variable has a natural range of variation identified by the coefficient of variation (CV). The calculated CV values were used as reference margins to account for natural variation in gymnastics coaches and judges. Post-test and retention values for each of the three visual search variables were compared to the CV for that variable in order to ascertain whether change had occurred or, whether results were due to natural fluctuation in search data. For example, if number of fixations natural range of variation was 5.47 to 6.58 and the experts' score was seven this would fall outside the natural range of variation and therefore any change towards seven fixations above 6.58 would suggest that a meaningful effect had occurred.

8.2.3.2 Changes in error

To examine whether post-intervention the trained participants visual fixation pattern became more closely aligned to that of the expert judges (chapter 3) temporal based error values for each of the five stages of the vault (as discussed in section 6.2.5) were calculated. This indicated whether the individual participants distributed their visual fixation in a manner that was more analogous to the experts' data from study three. For example, a participant might produce 6 fixations at baseline, post-test and retention, but by the retention they may be spread over the five phases more analogous to the experts rather than being all in one phase. Error values were calculated using the following formula.

Error (run up, hurdle step, first flight, second flight, landing)
= Actual value at each phase – Experts value at each phase

The experts values were obtained from the expert model presented in Table 6.2. Once the error had been calculated for each phase of each vault, negative values were then converted to positive values to obtain absolute error. Using the absolute error values the mean absolute error was taken for each vault. The mean absolute error for each of the five vaults was then calculated for each of the four time points (baseline, 3 weeks, post-test, retention).

To obtain error data for the outcome judgment, error values for each of the five vaults were calculated. This indicated whether the participants gave outcome judgments that were more analogous to the experts' data from study three. Error values were calculated using the following formula.

Error (for each vault)
= Actual value given for each vault – Experts value for each vault

Once the error had been calculated for each vault, negative values were then converted to positive values to obtain absolute error. The mean absolute error for each of the five vaults was then calculated for each of the four time points (baseline, 3 weeks, post-test, retention).

For all four of the dependent variables (number of fixations, fixation duration, number of areas fixated and outcome judgment), individual participants percentage change data were calculated to explore the amount of change in error taking place between the baseline and post-test, the baseline and retention stage and the post-test and retention stage. Percentage change data was calculated from the following equation.

$$\frac{V_2 - V_1}{V_1} \times 100 = \text{Percentage change}$$

To calculate the percentage change from baseline to post-test V_1 was equal to the individual's baseline value and V_2 was equal to the individual's post-test value.

For the baseline to the retention stage V_1 was equal to the individual's baseline value and V_2 was equal to the individual's retention value.
For the post-test to the retention stage V_1 was equal to the individual's post-test value and V_2 was equal to the individual's retention value.

Each cased is discussed individually and where possible similarities and differences between cases are highlighted in the conclusion section.

8.3 RESULTS AND DISCUSSION

8.3.1 Participant one - novice

8.3.1.1Changes in mean values across the four time points

Table 8.1: Changes in mean values and CV ranges for the four dependent variables across the four time points for participant one.

Dependent variable	Baseline mean	Range based on CV (9.7%)	During mean	Post-test mean	Retention mean
Number of fixations	6 [1]	5.5 - 6.5	6.4 [0.6]	6.6 [0.4] *	7.8 [0.8] *
Fixation duration	122.08 [68.07]	115.50 – 129.04	126.80 [63.35]	133.53 [56.62] *	170.34 [19.81] *
Number of areas fixated	2.2 [0.8]	1.9 – 2.5	2.0 [1.0]	2.2 [0.8]	2.2 [0.8]
Outcome judgment	9.32 [0.9]		8.64 [0.22]	8.64 [0.22]	8.6 [0.18]

[ ] error from experts value

* denotes test values outside the identified natural range of variation calculated in study one.

Participant one who was a novice coach with five years of experience made changes to their mean number of fixations and became closer to seven fixations at the post-test and retention stage compared to the baseline. Further to this, the post-test and retention changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering the mean number of fixations to values that were closer to the experts identified in study three. However, the error increased from 0.4 at the post-test to 0.8 at the retention stage showing that the full impact of the perceptual training programme was not retained. A full discussion of this finding is presented in section 8.3.1.2. This is an important finding given that a retention effect has not been investigated before with regards to number of fixations.

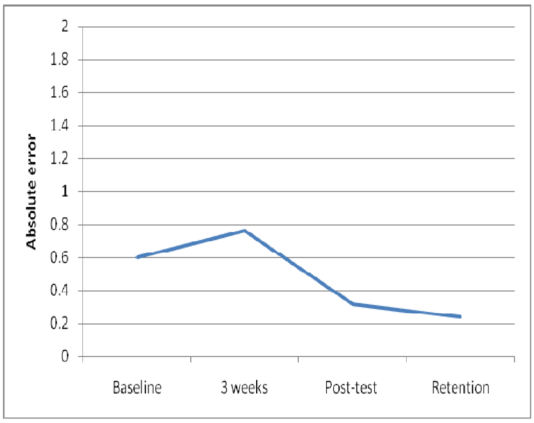
Participant one made changes to their fixation duration but became closer to the mean fixation duration of 190.15 at the post-test and retention stage than they were at the baseline. Further to this, the post-test and retention changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at modifying fixation duration to values that were closer to the experts. The mean results show that participant one retained the beneficial impact of the perceptual training programme and continued to become even more analogous to the experts values once the intervention was withdrawn.

Participant one made no changes to the number of areas fixated at the post-test and retention stage from baseline. This suggests that the perceptual training programme was not effective at changing the number of areas in which this participant fixated. It is interesting that although the number and duration of fixation s changed they appear to be located on a similar number of areas each time for this participant. Therefore, if researchers and applied practitioners want to increase or decrease the number of areas that a novice coach or judge fixate on then the perceptual training video used in this study based on fixation data and declarative knowledge may not be appropriate.

Participant one made changes to their outcome judgment and became closer to the experts judgment of 8.42 at the post-test and retention stage than they were at the baseline. This suggests that the perceptual training programme was effective at altering the outcome judgments to values that were closer to the experts for this participant. The ability to perform judgments that are closer to experts' judgments may be as a result of the more efficient visual search as demonstrated by the reductions in error for two of the three visual search dependent variables as indicated in table 8.1.

Although the changes in mean data are informative, the efficiency of visual search is often indicated by its temporal pattern. For example a gymnastics judge may need to distribute their fixation throughout the entire vault, rather than fixating only in the run-up. Therefore error values were calculated based on each stage of the vault and the mean values are presented in Figures 8.1 to 8.4.

8.3.1.2 Changes in error



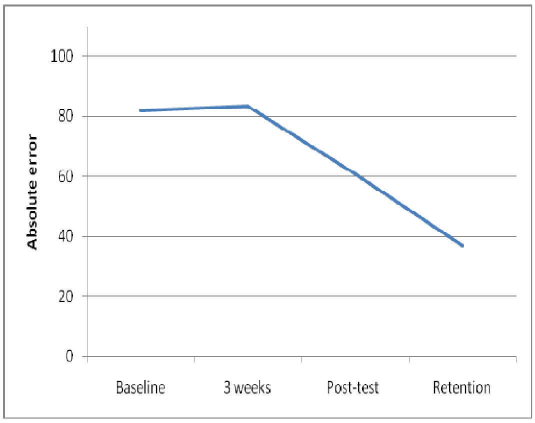
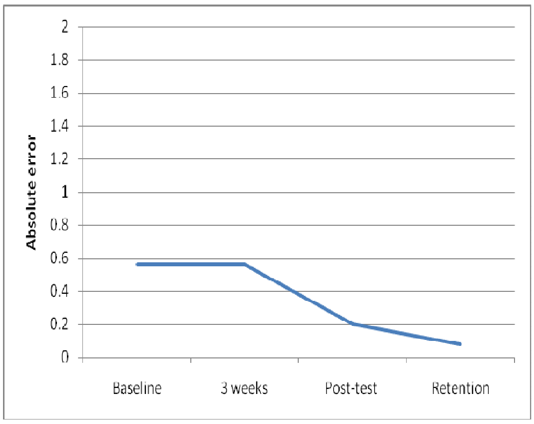


Figure 8.1: Absolute error values for number of fixations for participant one

Figure 8.2: Absolute error values for fixation duration for participant one



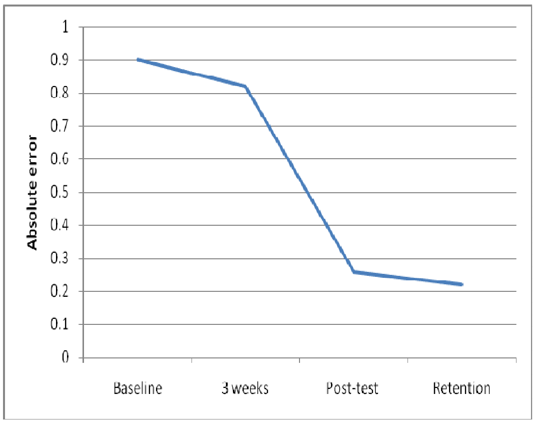


Figure 8.3: Absolute error values for number of areas fixated for participant one

Figure 8.4: Absolute error values for outcome judgment for participant one

Participant one increased in error by 26.7% from baseline (mean = 0.60) to three weeks (mean = 0.76), but decreased their error in the number of fixations by 46.7% from baseline (mean = 0.60) to post-test (mean = 0.32), by 60% from baseline (mean = 0.60) to retention (mean = 0.24) and by 25% from post-test (mean = 0.32) to retention (mean = 0.24). The reduction in error may be caused by enhancements in contextual knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling this participant to fixate appropriately. The numbers of fixation findings are particularly important given the large volume of research that has suggested that expert and novices produced significantly different number of fixations (e.g., Bard & Fleury, 1976; Helsen & Pauwels, 1992,1993; Mann et al., 2007; Moreno et al*.,* 2002; Ripoll et al., 1995; Savelsbergh et al*.,* 2002; Singer et al*.,* 1996; Vickers, 1996a, b).

Participant one increased their error 1.9% from baseline (mean = 81.91ms) to three weeks (mean = 83.46ms), but decreased their error in the fixation duration by 25.8% from baseline (mean = 81.91ms) to post-test (mean = 60.76ms), by 54.9% from baseline (mean = 81.91ms) to retention (mean = 36.95ms) and by 39.2% from the post-test (mean = 60.76ms) to the retention stage (mean = 36.95ms). The fixation duration findings suggest that a perceptual training programme aimed at altering both visual search patterns and declarative knowledge is effective at enabling novice coaches and judges to produce fixation durations that are similar to experts. The changes in fixation duration are perhaps due to enhancements in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling the participant to fixate within the display for more suitable lengths of time (Abernethy et al., 1999; Poulter et la., 2005; Williams et al., 2003). This is a particularly important finding given the large volume of research that has suggested that experts produce significantly different fixation durations than their novice counterparts (Helsen & Pauwels, 1992, 1993; Moreno et al., 2002; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996; Vickers, 1996a, b). Although the case study findings are limited based on one persons data, it appears that if the number of fixations and or fixation duration hinders performance of novice coaches and judges then a perceptual training programme based on experts declarative knowledge and eye-tracking patterns may facilitate visual search.

Participant one also one decreased their error in the number of areas fixated by 64.3% from baseline (mean = 0.56) to post-test (mean = 0.20), by 85.7% from baseline (mean = 0.56) to retention (mean = 0.08) and by 60.0% from post-test (mean = 0.20) to retention (mean = 0.08). This suggests that the perceptual training programme utilised in this study was effective at enabling this novice judge to produce similar numbers of areas fixated to expert coaches and judges. This reduction in error may be explained by changes in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling the participant to orientate their attention on more task relevant features (Abernethy et al., 1999; Poulter et al., 2005; Williams et al., 2003). This may have resulted in enhanced selective attention (Norman, 1968). This is an interesting finding because a relatively low number of studies have investigated the differences between experts' and novices' number of areas fixated. Should future studies continue to find differences in the number of areas fixated, similar to study two of this thesis, perhaps a perceptual training programme may help novice participants through knowledge enhancement and the orienting of visual attention.

Participant one decreased their error in outcome judgment by 9.0% from baseline (mean = 0.90) to three weeks (mean = 0.82), 71.1% from baseline (mean = 0.90) to post-test (mean = 0.26), by 75.6% from baseline (mean = 0.90) to retention (mean = 0.22) and by 15.4% from post-test (mean = 0.26) to retention (mean = 0.22). These changes in outcome judgment may have been caused by the re-distribution of the fixations throughout the handspring vault. For example, the attention to the gymnast's shoulders in the run-up may have enhanced their ability to anticipate the quality of the imminent movement suggesting a relationship or ability to project and build on information in forming upcoming judgments. A relationship between the use of early cues and enhanced judgments was found by Ste-Marie (1999).

Alternatively, given the nature of the training video, the improvements in outcome judgment may also be explained by the novices newly developed ability to selectively attend as indicated by the fixation number, fixation duration and number of areas fixated findings. Indeed, the perceptual training DVD used in this study was developed using only information that was frequently cited by most experts. Therefore the cues that were highlighted were limited to one to two areas per vault which could have encouraged the novices to rely only on the information given, rather than searching as much as possible which can result in attentional overload and reduced cognitive performance (Kahneman, 1973). This suggests that the development of selective attention may be an important factor for novice coaches and judges.

It could be argued that the highlighted areas of the body in the perceptual training DVD may have enhanced the intensity of the visual signal for the participant resulting in a reduction of surrounding perceptual noise and consequently enhancing signal detection (Swets, 1964). Therefore, the novice coaches and judges could have identified the cues quickly, and therefore had more time to process them in order to select the most appropriate outcome judgment.

Whilst these results must be treated with caution, given that they are based on a single case study, they do support alterations in visual fixations as potential mechanisms for enhancing the development of judgment formation for novice participants. This is supported by research that has found that perceptual training has an effect on visual search variables (Harle & Vickers, 2001) and decision making (Caserta et al., 2007). The outcome judgment findings show that a perceptual training programme aimed at changing both visual search patterns and declarative knowledge is effective at enabling a novice judge to produce outcome judgments that are similar to experts. This is perhaps the most interesting finding given that the most significant role of judges and coaches involves their ability to judge the quality of a performance. This would suggest that if a novice judge or coach wishes to improve and develop their decision making ability towards that of an expert then engaging in perceptual training programmes may be an effective intervention method for them.

8.3.2 Participant two - novice

8.3.2.1Changes in mean values across the four time points

Table 8.2: Changes in mean values and CV ranges for the four dependent variables across the four time points for participant two.

Dependent variable	Baseline mean	Range based on CV (9.7%)	During mean	Post-test mean	Retention mean
Number of fixations	4.2 [2.8]	3.8 - 4.6	6.8 [0.2]*	6.8 [0.2] *	6.6 [0.4] *
Fixation duration	100.80 [89.35]	95.36 – 106.55	151.06 [39.09]*	143.33 [46.82] *	146.66 [43.49] *
Number of areas fixated	2.0 [1]	1.8 – 2.3	2.2 [0.8]	2.4 [0.6] *	2.6 [0.4]*
Outcome judgment	9.32 [0.9]		9.34 [0.76]	9.18 [0.76]	9.08 [0.66]

[ ] error from experts value

* denotes test values outside the identified natural range of variation calculated in study one.

Participant two, who was a novice coach with one year of experience, made changes to their number of fixations and became closer to seven fixations at the post-test and retention stage compared to the baseline. Further to this, all changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering number of fixations to values that were closer to the experts for this participant.

Participant two made changes to their fixation duration and became closer to seven fixations at the post-test and retention stage compared to the baseline. Further to this, all changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering fixation duration to values that were closer to the experts for this participant. The fixation duration findings suggest that a perceptual training programme aimed at changing both visual search patterns and declarative knowledge is quite effective at enabling novice coaches and judges to produce fixation durations that are similar to experts. This is a key finding given the vast number of research papers that have shown that experts produce significantly different fixation durations than their novice counterparts (Helsen & Pauwels, 1992, 1993; Moreno et al., 2002; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996; Vickers, 1996a, b) and therefore if fixation duration limits the performances of novices then a perceptual training programme may be a suitable means of training them.

Participant two also made changes to the number of areas fixated and became closer to the expert's value of three at the post-test and retention stage than they were at the baseline. Further to this, participant twos changes were outside the natural range of variation at the post-test and retention. This suggests that the perceptual training programme was effective at altering number of areas fixated to values that were closer to the experts for this participant.

Participant two and made changes to their outcome judgment and became closer to the experts judgment of 8.42 at the post-test and retention stage than they were at the baseline. This suggests that the perceptual training programme was effective at altering the outcome judgments for this novice judge to values that were closer to the experts.

8.3.2.2 Changes in error

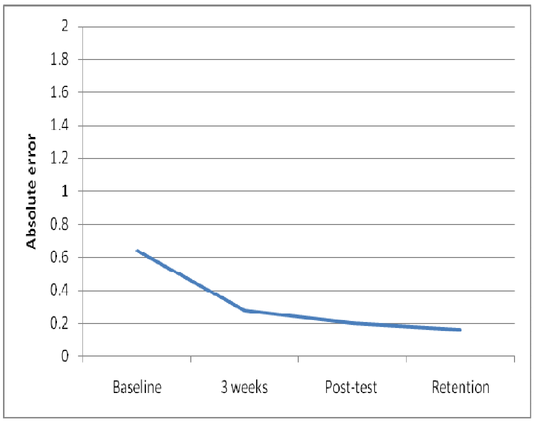


Figure 8.5: Absolute error values for number of fixations for participant two

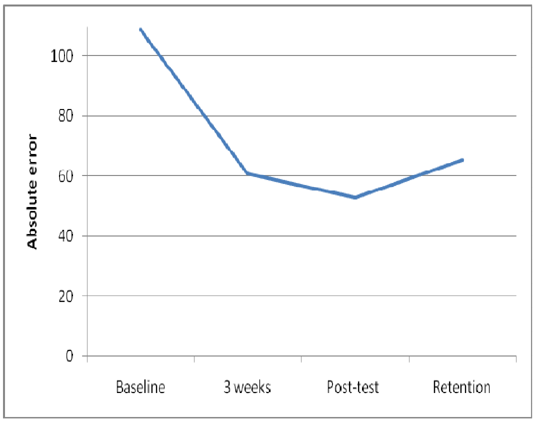


Figure 8.6: Absolute error values for fixation duration for participant two

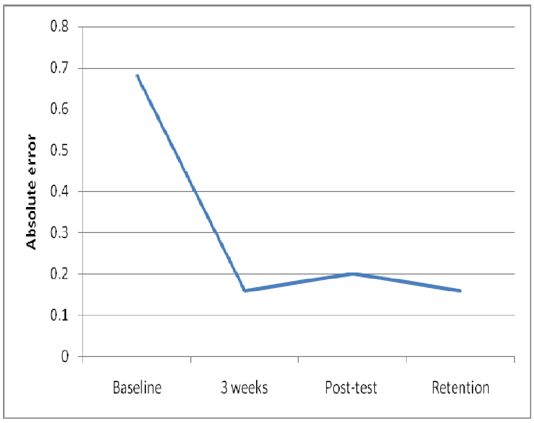


Figure 8.7: Absolute error values for number of areas fixated for participant two

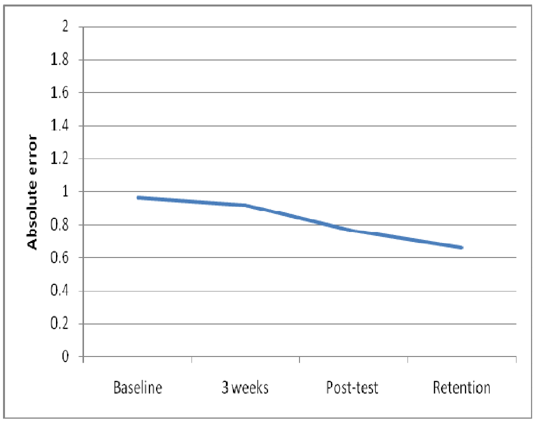


Figure 8.8: Absolute error values for outcome judgment for participant two

Participant two decreased their error in the number of fixations by 56.23% from baseline (mean = 0.64) to three weeks (mean = 0.28), 68.8% from baseline (mean = 0.64) to post-test (mean = 0.20), by 75.0% from baseline (mean = 0.64) to retention (mean = 0.16) and by 20.0% from post-test (mean = 0.20) to retention (mean = 0.16). Similar to participant one, the reduction in error may be caused by enhancements in contextual knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling them to fixate appropriately. This finding is particularly important given the large volume of research that has suggested that expert and novices produced significantly different number of fixations (e.g., Bard & Fleury, 1976; Helsen & Pauwels, 1992,1993; Mann et al., 2007; Moreno et al., 2002; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996; Vickers, 1996a,b). The findings of this case study suggest that if the number of fixations hinders performance of novice coaches and judges then a perceptual training programme based on experts declarative knowledge and eye-tracking patterns may be a valuable method of training them, through the enhancement of declarative knowledge and the effective orienting of visual attention.

Participant two decreased their error in the fixation duration by 44.0% from baseline (mean = 108.71ms) to three weeks (mean = 60.93ms), 51.2% from baseline (mean = 108.71ms) to post-test (mean = 53.01ms), by 39.9% from baseline (mean = 108.71ms) to retention (mean = 65.31ms) and by 23.2% from the post-test (mean = 53.01ms) to the retention stage (mean = 65.31ms). The fixation duration findings suggest that a perceptual training programme aimed at changing both visual search patterns and declarative knowledge is quite effective at enabling novice coaches and judges to produce fixation durations that are similar to experts. The impacts of the perceptual training video can be explained through the newly developed modifications in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling the participant to fixate within the display for more suitable lengths of time (Abernethy et al., 1999; Poulter et al., 2005; Williams et al., 2003). The changes in fixation duration are encouraging given the extensive amount of research that has suggested that experts produce significantly different fixation durations than their novice counterparts (Helsen & Pauwels, 1992, 1993; Moreno et al., 2002; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996; Vickers, 1996a, b). This finding suggests that if fixation duration constrains performances of novices then a perceptual training programme may be a suitable method of training them.

Participant two decreased their error in the number of areas fixated by 76.5% from baseline (mean = 0.68) to three weeks (mean = 0.16), 70.6% from baseline (mean = 0.68) to post-test (mean = 0.20), by 76.5% from baseline (mean = 0.68) to retention (mean = 0.16) and by 20.0% from post-test (mean = 0.20) to retention (mean = 0.16). This suggests that the perceptual training programme utilised in this study was reasonably effective at enabling novice coaches and judges to produce similar numbers of areas fixated to expert coaches and judges. These reductions in error may have been attributable to alterations in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling the participant to orientate their attention on more task relevant features (Abernethy et al., 1999; Poulter et al., 2005; Williams et al., 2003) and therefore enhanced selective attention (Norman, 1968). However, the results are not quite as consistent as the beneficial effects on the alteration of number of fixations given that the changes were only evident outside the natural range of variation for two participants. This is an interesting finding because a relatively low number of studies have investigated the differences between experts' and novices' number of areas fixated. Should future studies continue to find differences in the number of areas fixated, similar to study two of this thesis, perhaps a perceptual training programme may help novice participants.

Following a similar pattern to participant one, participant two decreased their error in the outcome judgment by 4.2% from baseline (mean = 0.96) to three weeks (mean = 0.92), 20.8% from baseline (mean = 0.96) to post-test (mean = 0.76), by 31.3% from baseline (mean = 0.96) to retention (mean = 0.66) and by 13.2% from post-test (mean = 0.76) to retention (mean = 0.66). These changes in outcome judgment may have been due to the re-distribution of the fixations throughout the handspring vault. For example, the attention to the gymnast's shoulders in the run-up may have enhanced their ability to anticipate the quality of the pending action (Ste-Marie, 1999).

Alternatively, given the nature of the training video, the improvements in outcome judgment can also be explained by the novices newly developed ability to selectively attend. Indeed, the perceptual training DVD used in this study was developed using only information that was frequently cited by most experts. Therefore the cues that were highlighted were limited to one to two areas per vault which could have encouraged the novices to rely only on the information given, rather than searching as much as possible. This suggests that the development of selective attention is an important factor for novice coaches and judges.

The improvements in outcome judgment can also be explained through the mechanism of enhanced signal detection (Swets, 1964). The highlighted areas of the body in the perceptual training DVD could have enhanced the intensity of the visual signal which should have reduced the surrounding perceptual noise. Therefore, the novice coaches and judges could have identified the cues quickly and had more time to process them in order to select the most appropriate outcome judgment.

Whilst these results must be treated with caution, given the case study approach adopted, they do support alterations in visual fixations as potential mechanisms for enhancing the development of judgment formation for novice participants. This is supported by research that has found that perceptual training has an effect on visual search variables (Harle & Vickers, 2001) and decision making (Caserta et al., 2007). The outcome judgment findings show that a perceptual training programme aimed at altering both visual search patterns and declarative knowledge is effective at enabling novice coaches and judges to produce outcome judgments that are similar to experts. This is perhaps the most interesting finding given that the most significant role of judges and coaches involves their ability to judge the quality of a performance. This finding suggests that if novices want to accelerate and become more like experts in terms of their decision making then a perceptual training programme may be an effective method of training them.

8.3.3 Participant three - novice

8.3.3.1Changes in mean values across the four time points

Table 8.3: Changes in the four dependent variables across the four time points for participant three.

Dependent variable	Baseline mean	Range based on CV (9.7%)	During mean	Post-test mean	Retention mean
Number of fixations	5.8 [1.2]	5.3 - 6.4	7 [0.0]*	7.6 [0.6] *	7.8 [0.8] *
Fixation duration	135.40 [54.75]	128.10 – 143.12	136.44 [8.95]	181.20 [8.95] *	169.26 [20.89]*
Number of areas fixated	2.2 [0.8]	1.9 – 2.5	2.4 [0.6]	2.6 [0.4] *	2.7 [0.3] *
Outcome judgment	6.82 [1.60]		7.16 [1.26]	7.16 [1.26]	7.16 [1.26]

[ ] error from experts value

* denotes test values outside the identified natural range of variation calculated in study one.

Participant three, who was a novice coach and judge with three years of experience, made changes to their number of fixations and became closer to seven fixations at the post-test and retention stage compared to the baseline. Further to this, all changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering number of fixations to values that were closer to the experts for this participant.

Participant three made changes to their fixation duration and became closer to mean fixation durations of 190.15 at the post-test and retention stage than they were at the baseline. Further to this, the post-test and retention changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at changing fixation duration to values that were closer to the experts for this participant.

Participant three and made changes to the number of areas fixated and became closer to the experts value of three at the post-test and retention stage than they were at the baseline (see error values in Table 8.3). Further to this, all changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering number of areas to values that were closer to the experts for this participant.

Participant three made changes to their outcome judgment and became closer to the experts judgment of 8.42 at the post-test and retention stage than they were at the baseline (see error values in Table 7.4). This suggests that the perceptual training programme was effective at altering the outcome judgments of novice coaches and judges to values that were closer to the experts.

8.3.3.2 Changes in error

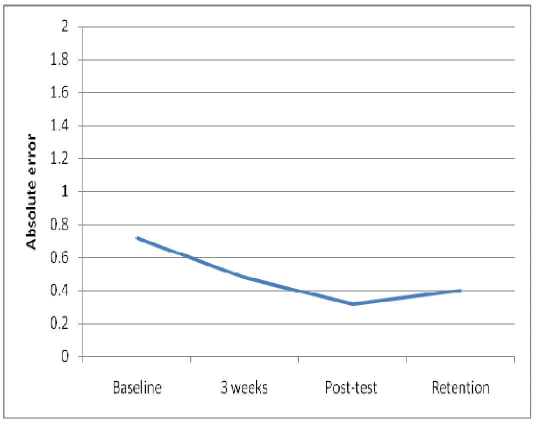


Figure 8.9: Absolute error values for number of fixations for participant three

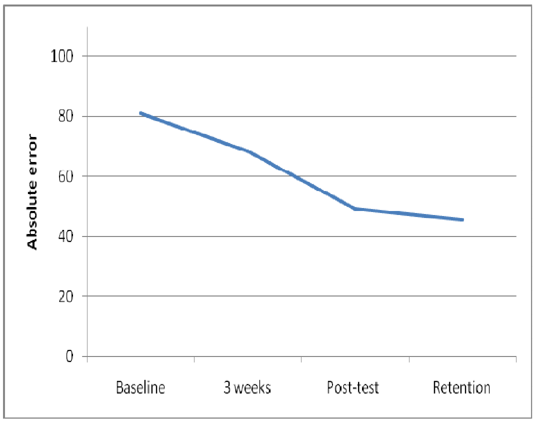


Figure 8.10: Absolute error values for fixation duration for participant three

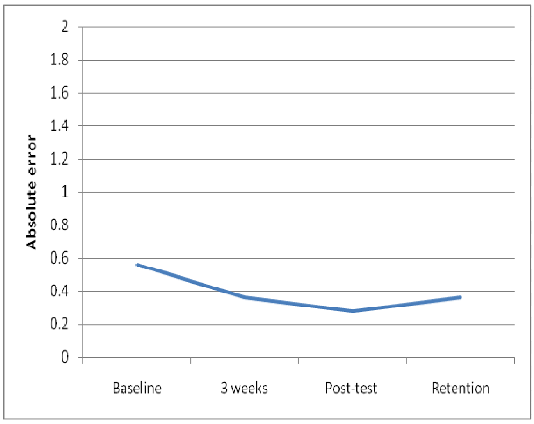


Figure 8.11: Absolute error values for number of areas fixated for participant three

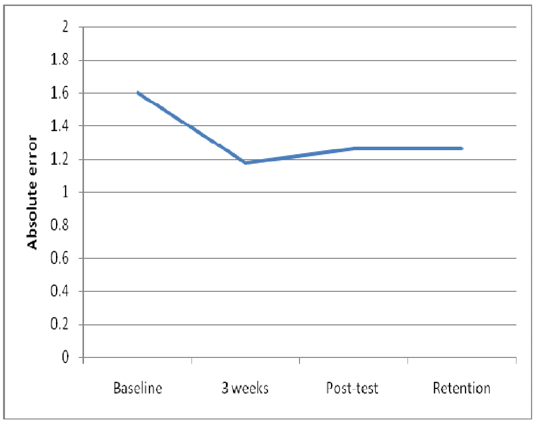


Figure 8.12: Absolute error values for outcome judgment for participant three

Similar to participant two, participant three decreased their error in the number of fixations by 33.3% from baseline (mean = 0.72) to three weeks (mean = 0.48), 55.6% from baseline (mean = 0.72) to post-test (mean = 0.32), by 44.4% from baseline (mean = 0.72) to retention (mean = 0.40) and by 25.0% from post-test (mean = 0.32) to retention (mean = 0.40). The reduction in error produced throughout the perceptual training programme can be attributed to enhancements in contextual knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling this participant to fixate the appropriate number of times throughout the vault. The numbers of fixation findings are particularly important given the large volume of research that has suggested that expert and novices produced significantly different number of fixations (e.g., Bard & Fleury, 1976; Helsen & Pauwels, 1992,1993; Mann et al., 2007; Moreno et al., 2002; Ripoll et al., 1995; Savelsbergh et al., 2002; Singer et al., 1996; Vickers, 1996a,b). The findings of the current study suggests that if the number of fixations hinders performance of novice coaches and judges then a perceptual training programme based on experts declarative knowledge and eye-tracking patterns may be an effective method of training visual search.

Participant three decreased their error in the fixation duration by 15.5% from baseline (mean = 81.14ms) to three weeks (mean = 68.56ms), 39.2% from baseline (mean = 81.14ms) to post-test (mean = 49.29ms), by 44.0% from baseline (mean = 81.14ms) to retention (mean = 45.45ms) and by 7.8% from the post-test (mean = 49.29ms) to the retention stage (mean = 45.45ms). The fixation duration findings suggest that a perceptual training programme aimed at altering both visual search patterns and declarative knowledge is quite effective at enabling novice coaches and judges to produce fixation durations that are similar to experts. The reduction in error can be explained through the changes in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) enabling the participant to fixate within the display for more suitable lengths of time (Abernethy et al., 1999; Poulter et al., 2005; Williams et al., 2003). This is important because Helsen and Pauwels (1992, 1993), Moreno et al. (2002), Ripoll et al. (1995), Savelsbergh et al. (2002), Singer et al. (1996) and Vickers (1996a, b) all found that experts produce significantly different fixation durations than novices. This finding suggests that if fixation duration hinders performances of novices then a perceptual training programme may be an appropriate means of training them.

Similar to participant one, participant three also decreased their error in the number of areas fixated throughout the intervention. Participant three decreased their error by 35.7% from baseline (mean = 0.56) to three weeks (mean = 0.36), 50.0% from baseline (mean = 0.56) to post-test (mean = 0.28), by 35.7% from baseline (mean = 0.56) to retention (mean = 0.36) and by 28.6% from post-test (mean = 0.28) to retention (mean = 0.36). This suggests that the perceptual training programme utilised in this study was reasonably effective at enabling novice coaches and judges to produce similar numbers of areas fixated to expert coaches and judges. These reductions in error may have been caused by modifications in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) causing more refined selective attention to more pertinent areas (Norman, 1968). This is an interesting finding because a relatively low number of studies have investigated the differences between experts' and novices' number of areas fixated. Should future studies continue to find differences in the number of areas fixated, similar to study two of this thesis, perhaps a perceptual training programme may help novice participants.

Participant three decreased their error in the outcome judgment by 26% from baseline (mean = 1.60) to three weeks (mean = 1.18), 21% from baseline (mean = 1.60) to post-test (mean = 1.26), and by 21% from baseline (mean = 1.60) to retention (mean = 1.26). Participant three did not show any change from post-test to retention (mean = 1.26). These changes in outcome judgment may have been caused bythe re-distribution of the fixations throughout the handspring vault. For example, the attention to the gymnast's shoulders early in the run-up phase may have enhanced their ability to anticipate the quality of the imminent movement (Ste-Marie, 1999).

Alternatively, given the nature of the training video, the improvements in outcome judgment can also be explained by the novices newly developed ability to selectively attend. Indeed, the perceptual training DVD used in this study was developed using only information that was frequently cited by most experts. Therefore the cues that were highlighted were limited to one to two areas per vault which could have encouraged the novices to rely only on the information given, rather than searching as much as possible. This suggests that the development of selective attention is an important factor for novice coaches and judges.

The improvements in outcome judgment can also be explained through the mechanism of enhanced signal detection (Swets, 1964). The highlighted areas of the body in the perceptual training DVD could have enhanced the intensity of the visual signal which should have reduced the surrounding perceptual noise. Therefore the novice coaches and judges could have identified the cues rapidly and therefore had more time to process them in order to choose the most appropriate outcome judgment.

Whilst these results must be treated with caution, given the low participant numbers, they do support alterations in visual fixations as potential mechanisms for enhancing the development of judgment formation for novice participants. This is supported by research that has found that perceptual training has an effect on visual search variables (Harle & Vickers, 2001) and decision making (Caserta et al., 2007). The outcome judgment findings show that a perceptual training programme aimed at changing both visual search patterns and declarative knowledge is effective at enabling novice coaches and judges to produce outcome judgments that are similar to experts. This is perhaps the most interesting finding given that the most significant role of judges and coaches involves their ability to judge the quality of a performance. This finding suggests that if novices want to accelerate and become more like experts in terms of their decision making then a perceptual training programme may be an effective method of training them.

8.3.4 Participant four – expert

8.3.4.1Changes in mean values across the four time points

Table 8.4: Changes in the four dependent variables across the four time points for participant four.

Dependent variable	Baseline mean	Range based on CV (9.7%)	During mean	Post-test mean	Retention mean
Number of fixations	7.8 [0.8]	7.11 – 8.56	6.6 [0.4]*	8.8 [1.8]*	7.2 [0.2]*
Fixation duration	153.10 [37.05]	144.84 – 161.83	193.6 [29.67]*	219.82 [29.67]*	208.46 [18.31]*
Number of areas fixated	2.0 [1.0]	1.8 – 2.3	2.0 [1.0]	2.4 [0.6]*	2.6 [0.4]*
Outcome judgment	7.84 [0.58]		7.74 [0.68]	8.12 [0.30]	7.32 [1.10]

[ ] error from experts value

* denotes test values outside the identified natural range of variation calculated in study one.

Participant four, who was an expert coach and judge with 20 years of experience, did not replicate the novice data trend. The expert participant produced higher mean error for the number of fixations per vault at the post-test. This suggests that the perceptual training programme was not effective at enabling the expert participant to produce the analogous visual fixation number as the experts' data from study three of this thesis. However, the mean data shows that less error was produced at the retention stage. Interestingly, the mean data for the three week measure also shows less error. Therefore it appears that this participant experience an interference effect at the post-test but recovers from this throughout the four week retention period.

Participant four made changes to their fixation duration and became closer to mean fixation durations of 190.15 at the post-test and retention stage than they were at the baseline. Further to this, all changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering fixation duration to values that were closer to the experts for this participant. The beneficial impacts of training expert participants have also been shown by Caserta et al. (2007).

Participant four also made changes to the number of areas fixated and became closer to the experts value of three at the post-test stage than they were at the baseline. However, their error was increased at the retention stage. Further to this, all changes were outside the natural range of variation. This suggests that the perceptual training programme was effective at altering number of areas to values that were closer to the experts for this participant, but this effect was not retained once the intervention had been withdrawn. This suggests that although a perceptual training programme may alter specific aspect of visual search, the retention of these effects requires greater exploration.

Participant four made changes to their outcome judgment and became closer to the experts judgment of 8.42 at the post-test stage, but produced values that were further away for the expert values at the retention stage. Again, this suggests that perceptual training programme may have an immediate impact on decision making for experts. However, the effects are not retained once the intervention has been withdrawn.

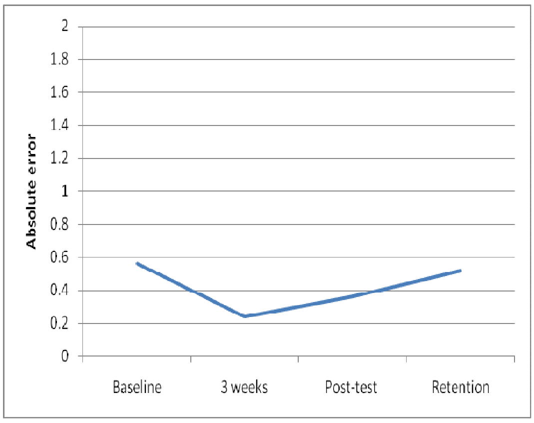


Figure 8.13: Absolute error values for number of fixations for participant four

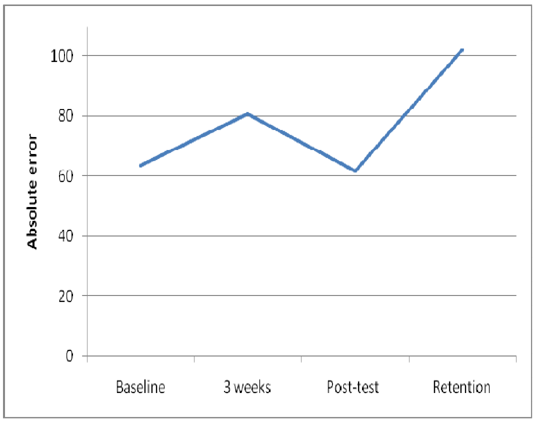


Figure 8.14: Absolute error values for fixation duration for participant four

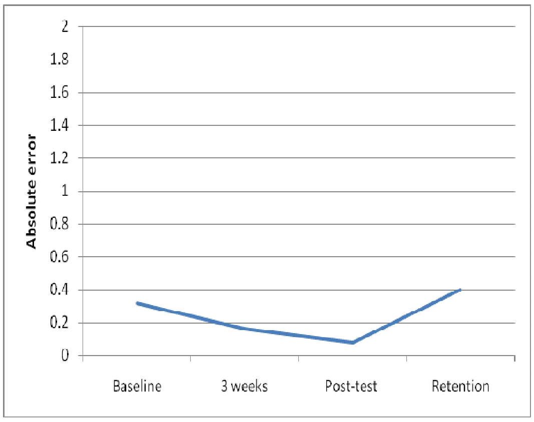


Figure 8.15: Absolute error values for number of areas fixated for participant four

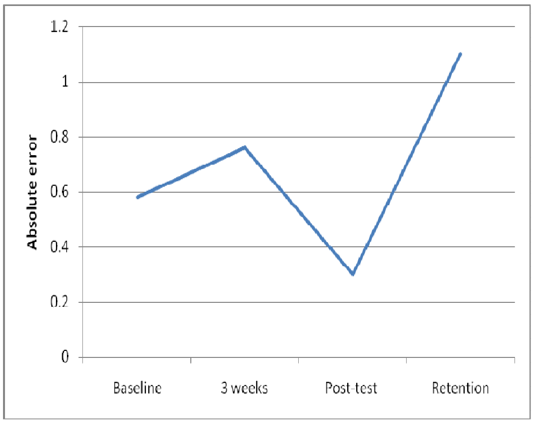


Figure 8.16: Absolute error values for outcome judgment for participant four

The expert participant experienced decreased error in the number of fixations by 57.1% from baseline (mean = 0.56) to three weeks (mean = 0.24), 35.7% from baseline (mean = 0.56) to post-test (mean = 0.36) and by 7.1% from baseline (mean = 0.56) to retention (mean = 0.52). The expert participant increased error in the number of fixations by 44.4% from the post-test (mean = 0.36) to retention (mean = 0.5). This suggests that a perceptual training programme aimed at changing both visual search patterns (through highlighting visual cues) and declarative knowledge (by presenting knowledge statements on a freeze framed screen) is effective at enabling an expert coach/judge to produce fixation numbers that are similar to a group of experts. The slight reduction in error at the post-test stage may have been caused by slight alterations in declarative knowledge (Abernethy et al., 1994; Adelson, 1984; Chi & Glaser, 1980; Chi et al., 1981) which were then not retained. The increase in error at the retention stage can be explained by the established cognitive maps of the expert, which are perhaps more difficult to alter and therefore a six week programme was perhaps not long enough to make the changes to the cognitive maps permanent. Future research could concentrate on examining the impact of perceptual training programme length on the retention effects of expert coaches' and judges' visual search. These findings suggest that although the perceptual training programme may alter the visual search of an expert coach/judge, to make long term changes the programme would have to be reinforced more.

The expert participant experienced increased error from baseline (mean = 63.47ms) to three weeks (mean = 80.62 ms) by 27.0%, but showed decreased error in fixation duration by 2.5% from baseline (mean = 63.47ms) to post-test (mean = 61.89ms). The expert participant experienced increased error in fixation duration by 61.0% from baseline (mean = 63.47ms) to retention (mean = 102.19ms) and by 65.1% from the post-test (mean = 61.89ms) to retention (mean = 102.149ms). To support the ineffectiveness of the programme based on mean data, the error values in the temporal phase analysis also show that the perceptual training programme was ineffective at reducing the error by phase. The increase in error for the fixation duration may be explained in two ways. Firstly, the intervention may have caused an interference effect within the information processing stages of the expert. This is reflected by the mean error value per vault being quite low at baseline (8.07ms) and then much higher at the retention stage (53.41ms). Therefore perceptual training programmes may interfere with previously learned methods of observation and therefore result in disrupted visuals search patterns. This effect appears similar to the contextual interference effect proposed by Battig (1972) where increased cognitive processing interrupts the manner in which participants would normally make decisions (Masters, 1992; Maxwell, Masters & Eves, 2000).

Secondly, due to the difficulty of highlighting the fixation duration on the perceptual training videos, the important areas of the body were highlighted throughout the entire phase. This may have caused the much longer fixation duration displayed by the expert. This is a potential limitation of the development of the perceptual training DVD's utilised in this study. More generally, the fixation duration findings suggest that if the fixation duration hinders performance of an expert then a perceptual training programme is not an appropriate means of training them.

The expert participant experienced decreased error in the number of areas fixated by 50.0% from baseline (mean = 0.32) to three weeks (mean = 0.16), 75.0% from baseline (mean = 0.32) to post-test (mean = 0.08). The expert participant experienced increased error in the number of areas fixated by 25.0% from baseline (mean = 0.32) to retention (mean = 0.40) and by 400.0% from the post-test (mean = 0.08) to retention (mean = 0.40). Similar to the number of fixations findings, the increase in error of the number of areas fixated at the retention stage can be explained by the established cognitive maps of the expert. These may be difficult to change and therefore experts may require increased reinforcement to make long term adaptations to the number of areas on which they fixate. Again, it is recommended that future research could concentrate on examining the impact of perceptual training programme length on the retention effects of expert coaches and judges' visual search.

The expert participant experienced increased in error by 31.0% from baseline (mean = 0.58) to three weeks (mean = 0.76), but showed decreased error in outcome judgment by 48.3% from baseline (mean = 0.58) to post-test (mean = 0.30). The expert participant experienced increased error in the outcome judgment fixated by 89.7% from baseline (mean = 0.58) to retention (mean = 1.10) and by 266.7% from the post-test (mean = 0.30) to retention (mean = 1.10). The outcome judgment results also mirror the fixation duration results whereby this participant shows greater error during the intervention, alluding to an interference effect. The retention results indicate that the perceptual training programme was ineffective at enabling an expert coach/judge to produce outcome judgments that are similar to a group of experts. These data reinforce the presence of an established cognitive map that is only altered when engaging with the training programme. Once the programme is withdrawn the expert appears to revert back to above baseline levels of error for the outcome judgment. There also appears to be an interference effect once the perceptual training programme is withdrawn, with the participant displaying higher error than at baseline levels. These outcome judgments findings suggests that a perceptual training programme based on training declarative knowledge and visual search patterns is not effective at training the outcome judgments of an expert coach/judge towards an expert model in the long term.

8.4 CONCLUSION

The findings from this study highlight a number of important implications. Most importantly the perceptual training DVD was effective at enabling the novices to produce mean fixation numbers and fixation durations closer to the experts at the post-test and retention stages. The perceptual training DVD had varied effects on the number of areas fixated. For example, based on the mean values per vault the perceptual training programme only had a positive effect at the retention stage for two participants for number of areas fixated. This suggests that in relation to the assessment of the mean values per vault, the perceptual training programme had different impacts upon the participants. This was the first study to look at the individual impacts of a perceptual training programme on visual search variables and implies that perceptual training programmes may not be a suitable method of training all participants if the mean values per vault are being assessed.

To counter this, the temporal phase analysis shows conflicting results. The phase analysis shows that the perpetual training programme was effective at reducing error per phase of the vault (based on the experts' values) for all three novice participants for the number of fixations, fixation duration and number of areas fixated. This suggests that they had become more alike the expert within the five specific phases of the vault. From the error by phase analysis it would be appropriate to conclude that the perceptual training programme was effective at altering the visual fixation distribution of the novice coaches and judges. This can be explained through adaptations in knowledge of the novice participants, which can impact upon the cognitive maps which direct attention.

The contradictions based on a comparison of the mean data per vault and mean data per phase of the vault imply that the changes in mean values alone might not be the best method of understanding the impact of perceptual training programmes. Therefore, it is recommended that future research assess changes in search using distribution of fixations as well as overall mean data to show the intricacies of changes in distribution of fixations which could aid performance. For example, changing from 7 to 7.2 fixations may not be statistically significant, but distributing them so that the performer fixates twice in the run up, once in each of the flight phases, and twice during the landing rather than 7 fixations during the run up phase could result in a better performance analysis.

Furthermore, the variations of the impact of the perceptual training programme within the three visual fixation variables (e.g., two of the three participants produced lower error in the number of areas fixated at the retention stage) show that a perceptual training programme based on experts declarative knowledge and visual search programmes may not be a suitable method of training all novice coaches and judges in gymnastics. In contrast to this, the error by phase data show that perceptual training programmes based on experts declarative knowledge and visual search are a suitable method of training all novice and coaches, given that error was reduced from baseline at the retention stage for all participants.

A prominent feature of these data is the evidence of a retention effect by the novice participants who underwent the six week perceptual training programme. This is the first perceptual training study to include a retention stage when measuring visual search variables, and despite the limited number of participants involved, the error by phase analyses suggest that training effects continued and, perhaps more remarkably, improved within a four week period after the training programme was withdrawn. This has significant implications for the use of training programmes that include both explicit instructions and guided discovery elements early in coaches and judges careers, which may have long term benefits for coaches and judges. However the limited retention effect by the expert participant questions the use of pre-post test designs in perceptual training research. For example, Caserta et al. (2007) found that senior tennis players produced faster response speed, response accuracy and decision making at a post-test. However, the current study suggests that these changes may not be retained once the intervention is withdrawn, negating the effect of perceptually training the players at all. However, the Caserta et al. (2007) used experienced senior players rather than the top ranked (or expert) players therefore it is not possible to generalise the effects of withdrawing the perceptual training programme. Further research examining retention effects of perceptual training programmes for different levels of participants would be a welcome addition to the literature.

In addition to the quantitative data, the expert who underwent the social validation interview when asked ‘could you tell me whether you thought the intervention was useful to you’ replied

‘*to me personally not very*’ but later qualified this statement saying ‘*for new judges and coaches seeing a variety of the same skill being done well and badly with different faults is good, it will be good for them because they will have limited experience of seeing a big variety of vaults*’.

Interestingly, the expert in the perceptual training condition suggested that they felt that novice coaches and judges would benefit from the perceptual training intervention suggesting that they also felt that the benefits of the training programme would extend beyond themselves.

8.4.1 Implications

In order to further the current literature regarding perceptual training in sport, the perceptual training DVD utilised in this study was developed based on the trends of visual search patterns and knowledge base of eight experts. This was signified by placing light circles around the areas of importance, combined with freeze frames showing what the experts were looking for. There have been very few studies that have aimed to assess the impact of training both visual search and declarative knowledge and this study adds to the reported effectiveness of this particular training technique for novice coach and judge populations.

It appears that a combination of both declarative knowledge in the form of written statements and visual search patterns through highlighting areas of the body does appear to be useful for training novices’ judgments, but the relative contributions of declarative knowledge and visual search in the training of judgment formation are not known. An alternative method would have been to test training videos that contain only knowledge and only visual search. However, positive findings from the perceptual training and anticipation literature (McMorris & Hauxwell, 1997; Williams & Burwitz, 1993) indicate that a combination is the most effective approach. Additionally, it would be interesting to investigate whether the knowledge base of the participants changed throughout this study. The changes in visual search, based on top-down processing, would suggest that the novices have undergone changes in their knowledge base, but the extent to which this has happened would need to be established using interviews.

Whilst this study advocates the use of perceptual training programme for training novice coaches and judges, these results must be interpreted with caution. The beneficial impact of the training programme on judgment formation may have been influenced by the coaching and judging that they had completed in between the pre and post tests, although it was ensured that the participants had not undergone any formalised training.

To conclude, this study suggested that the perceptual training programme was effective at altering key components of visual search patterns and outcome judgments of novice coaches and judges in gymnastics at both the post-test and retention stage. The participants who underwent the perceptual training programme made changes to their visual search and outcome judgments towards to the expert model (developed from the study three data from this thesis). This study also suggested that the perceptual training programme was effective at altering elements of visual search and outcome judgments of the expert coach/judge at the post-test. However, the effects of the programme were not retained after the intervention was withdrawn.

General Discussion

This chapter synthesises and explores the findings of the thesis in relation to previous research conducted on visual search in sport. This includes focussing on the uniqueness of this research programme and the significant additions to knowledge.

9.0 GENERAL DISCUSSION

The initial aim of this thesis was to investigate how to develop and assess the effectiveness of a perceptual training programme designed for coaches and judges of women's artistic gymnastics. Through doing this, the research programme has made significant additions to the perceptual training literature based on a number of scientific methods. The additions to the literature are illustrated below and discussed in the following paragraphs.

1) An understanding of the consistency of visual search for coaches and judges in gymnastics. This was identified in study one and then used as a frame of references for the effectiveness of the training programmes in study four.

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2) The application of perceptual training for coaches and judges in sport. This has not previously been investigated and was therefore the focus for all four studies in this thesis.

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3) The inclusion of a detailed analysis of visual search throughout the entire vault for analysis. This detailed analysis of the entire vault took place for all four studies and therefore gives a rich depth to the data and training videos.

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4) The inclusion of a unique and thoroughly documented approach to developing a training video which can be replicated by other researchers.

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5) An examination of a six week training programme

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6) The unique inclusion of a testing period four weeks after the perceptual training programme was completed (retention stage) for the evaluation of the intervention programme in study four.

9.1 Understanding of the consistency of visual search

This thesis found that coaches' and judges' visual search patterns were consistent when viewing identical performances approximately four weeks apart. The consistency of visual search has not previously been documented within the sports science literature. Therefore this research programme has determined that visual search for this population is consistent, and will allow researchers to attribute any changes in visual search that they find to the experimental manipulations that they are testing, rather than natural variation. For example, Williams et al. (2002) reported that visual search became more variable under high anxiety conditions. However, the consistency of visual search under conditions with no anxiety was not reported, leaving unanswered questions regarding natural variation. However, the findings of this thesis would suggest that visual search is stable to between 5.7% and 14.2% and therefore significant changes found by Williams et al. (2002) in low and high anxiety conditions are likely to be due to the experimental manipulation.

Furthermore, to assess the effectiveness of perceptual training programmes sound pre-tests have been performed to check that the variables are consistent to start with. Therefore, future research aimed at training visual search using similar populations and tasks to this study may now be able to rely on one baseline data collection and apply the coefficient of variation range identified in study one in order to represent typical pre-test visual search patterns. This will enable researchers to assess whether their intervention has made changes to visual search outside the identified natural range of variation, representing an actual shift in search patterns rather than natural fluctuation.

9. 2 The application of perceptual training for coaches and judges

This thesis is the first research programme to attempt to investigate the impact of perceptual training for coaches and judges in sport. This is surprising given that coaches and judges rely entirely on perceptual expertise. Sports performers alternatively also require expert physiology, tactical expertise, and technical expertise in order to be able to perform (Janelle & Hillman, 2003). This suggests that two populations that might benefit most from perceptual training are coaches and judges. Indeed, this thesis has found some very positive effects with regards to the impact of perceptual training for coaches and judges, particularly with regards to novice coaches and judges. However, the design of the study with regards to gaining detailed data over a long time period has prevented the calculation of power values, thus comparisons with regards to how helpful the training programmes are to coaches and judges compared with sports performers cannot be made.

9.3 Detailed analysis of visual search

This research employed a detailed analysis (frame by frame for the entire vault) in order to identify the critical cues for the perceptual training DVDs. This enabled the identification of the cues that were utilised at the different stages of the handspring vaults (run up, hurdle step, first flight, second flight, and landing). This temporal patterning is important for training purposes given that different cues were utilised at different phases of the vault.

There have only been three previous studies that have attempted to train visual search within the sports literature. The duration of the period of data that the researchers have collected in order to assess changes in visual search range from the duration of a fixation which could be as little as 99.9ms (Adolphe et al., 1997; Harle & Vickers, 2001) to one second of data (Poulter et al., 2005). Such limited time gives only a brief snapshot of the changes that are made in terms of the perceptual strategies and may mask some of the effect that the programme is having. For example, although quiet eye has been identified as important to sporting performance (Vickers, 1996a,b) the fixations prior to and post ball release may also be important and the studies by Adolphe et al. (1997) and Harle and Vickers (2001) do not take this into account. Poulter et al. (2005) have provided longer periods of analysis of one second in duration. However, given that much research has identified the use of early cues as part of experts' perceptual strategy (Abernethy & Russell, 1987) this limited analysis will not allow changes in the use of early cues to be identified. The present thesis analysed eye movements throughout the entire performance of the handspring vaults allowing changes in eye tracking to be identified throughout the entire vault. This would seem necessary for assessing developments in perceptual strategy.

9.4 Thoroughly documented approach to developing a perceptual training DVD

This thesis is the first to coherently document the step-by-step stages of the perceptual training video and importantly it has absorbed ideas from other researchers suggesting that perceptual training videos should combine eye-tracking and other measure of information extraction (Williams & Davids, 1997). Indeed rigorous eye tracking procedures were employed and these were combined with data collected from semi-structured interviews allowing an accurate picture to be formed of what experts were doing in the judgment formation process.

This research design aimed to address the comment suggested by Williams and Grant (1999, p211) that "a detailed understanding of the specific sources of information employed during skilled perception is an essential prerequisite to the development of effective perceptual training in sport". This was completed by documenting the eye-tracking and semi-structured interviews methods utilised to collect these data. However, previous to this, various methods of training have been utilised in the perceptual training literature.

The most recent perceptual training study in sport used a five day training period and reported that participants were instructed about “the cues that provide the most useful information with regards to where a shot will be hit” (Caserta et al., 2007, p. 485). However, Caserta et al. (2007) do not report where they got this information from. Therefore the important cues may be based on one person’s ideas as to what the important cues are or could be based on biomechanical performance analysis of the shots. The impact of not providing this critical data means that such studies cannot be replicated. Williams et al. (2002) based their explicit instruction programme on visual search data collected from a scientific study of eight expert participants and these were coupled with freeze frames and slow motion to show the relationship between the cues and shot placement. Exactly how the cues were highlighted is not clear in the study. Additionally, the explicit instruction group were also given formal instruction on the biomechanics of different strokes. However, it is not clear whether the biomechanical information was based on one person’s performance or a variety of experts, again making it problematic to replicate the design. Abernethy et al. (1999) also utilised formal instruction on biomechanics of shot, but again do not state where this information came from. In addition, Abernethy et al. (1999) also included formal instruction on locating the most important anticipatory cues. However, how they determined the most important anticipatory cues have not been stated in their research.

Interestingly, Mascarenhas et al. (2005) based their decision making training programme on only one person’s idea of what the correct decision should be, perhaps demonstrating a weakness in terms of video design. These poorly documented methods prevent researchers from replicating the research and deny the opportunity to compare the best methods of perceptual training. In essence, the structured development of the training

DVD documented within this research programme addresses many of these concerns.

9.5 The unique inclusion of a six week perceptual training programme

This thesis also aimed to develop the quality of the perceptual training literature by providing a training programme that lasted throughout a six week period. Study four of this thesis is only the second research study to investigate the impact of a six training period on visual search variables in sport. The study was designed to allow the participants repeated exposure (twice per week) of relevant perceptual information. This aimed to reinforce the experts' knowledge and eye-tracking patterns regularly to aid the leaning process. The impact of the training DVD was positive this suggesting that a repeated exposure technique is an effective way of training novice coaches and judges.

Previous research has failed to use a repeated exposure technique. For example, Adolphe et al. (1997) developed a six week on court perceptual training programme. However, only one session was explicitly dedicated to providing visual search information. The other five sessions were practically orientated, but the paper does mention that the practical tasks were designed to facilitate early detection and improved tracking of the ball. This programme did have an impact on visual search variables however, the authors note the limitation of their statistics being based on three participants.

Other research has used substantially shorter perceptual training interventions. Both Harle and Vickers (2001) and Poulter et al. (2005) only conducted one perceptual training session and found changes to varying aspects of vision such as quiet eye duration (Harle & Vickers, 2001) and percentage viewing time on 'relevant' areas (Poulter et al., 2005) by athletes. Williams et al. (2002) and Williams et al. (2003) also conducted one perceptual training session between the pre and post tests. A problem with this limited design is that further improvements may have happened had they trained the participants over a longer period and that the full extent of the training has been over looked. To substantiate this point, the novices in study four continued to make improvements having partaken in six perceptual training sessions even after it had been withdrawn.

9.6 The unique inclusion of a retention stage for the evaluation of the intervention programme

Importantly, this research found a retention effect for the benefits of the perceptual programme for some of the novice coaches and judges. A retention effect in relation to eye tracking has never before been investigated within the perceptual training in sport literature. Prior to this research, the researchers that have utilised pre-post designs in perceptual training studies have implied that changes made after the perceptual training programme, such as the faster response speed, higher percentage of accurate responses and higher percentage of performance decision making made by the tennis players in post-tests (Caserta et al., 2007) are long term. However, this study suggests that changes made as a result of perceptual training may only be applicable to specific participants, and for others a retention effect does not occur. The implication of this is that the tennis players who were trained in the Caserta et al. (2007) may not be able to reproduce the improvements after a period of no training, negating the effect of training the players initially. Further research is warranted in order to understand the retention effects of perceptual training, particularly with regards to visual search variables.

9.7 Limitations

The data collection in this thesis took place within a controlled setting with participants watching videos rather than live performance. An issue with live performance is that the researcher has no control over the quality of the gymnasts' performance and therefore training effects and between-group comparisons are difficult to conduct (Williams & Ericsson, 2005). In designing these studies, it was essential to control the data comparison to allow inter and intra individual and group comparisons. The transfer to live scenarios has therefore not been tested but given the nature of judging performance and the reliance only on the ventral stream, this thesis has not separated perception and action and therefore it is assumed that such conditions do indeed closely replicate real-life performance. In addition, Williams, Ward, Smeeton and Allen (2004) suggest that training perception is equally as effective as training perception and action.

A primary limitation inherent in most visual search based research is the low participant numbers involved. The low participant numbers involved are primarily due to the intensive time needed during the analysis process (Williams & Ericsson, 2005). Many researchers overcome this by using automated analysis or by examining specific components of visual search (e.g., quiet eye; Vickers, 1996). However, this was not deemed appropriate for training of the specific population involved in this study, given the dynamic nature of the displays that they are looking at and the many potential areas of the display the participants could fixate on. To surmount this issue, power values were calculated where possible and the resultant power values were strong (above 0.8 as indicated by Thomas et al., 2005). In addition the participant numbers utilised throughout this research programme (between eight and twenty) are comparable to participant numbers utilised in other published research papers in the field (e.g., Moreno et al., 2002, n=6; Ripoll et al., 1995, n=18; Savelsbergh et al., 2002, n= 14).

Furthermore utilising small numbers of participants limits the statistical analyses that can be performed on the data. However, robust inferential statistics have been employed where appropriate and effect sizes are reported. The limitations of using inferential statistics on small participant numbers have been acknowledged throughout the thesis.

Another limitation in this study regards the eye-tracking system. The ASL 501 is only accurate to one-to-two degrees of visual angle based on an accurate calibration. To ensure calibrations were accurate the system was piloted over a three month period, and the trace of the eyes were checked post analysis (using eyenal) to ensure that the software was reading the actual eye-movements throughout the testing period. Only readings where the eye was registered were used in the analysis, which resulted in losing three participants' data in studies one and two, and one participant's data in studies three and four.

9.8 Delimitations

All the studies involved in this thesis have utilised an ASL 501 eye-tracker system. This eye-tracker identifies central point of gaze using the pupil and corneal reflex therefore peripheral vision cannot be measured. Despite this the ASL systems are the most frequently used tool to-date and appear appropriate for use in sport contexts (Williams et al., 1999). To overcome this delimitation in study three where peripheral vision was considered important, interviews were conducted to allow participants to verbalise where they were looking. However, the use of peripheral vision in this process can only be assumed.

9.9 Recommendations for future study

This thesis has furthered the research in the area of perceptual training in sport. However, it has also highlighted a number of areas that need developing in order to determine the most appropriate methods to perceptually train sport participants and observers.

Firstly, this thesis found no significant differences in the outcome judgments of expert and novice coaches' and judges'. Therefore it appears that the task used within this study (judging a handspring vault) was not suitable for distinguishing between experts and novices. Future research should therefore determine tasks that are better suited to highlighting potential differences between expert and novice performers or observers (Ward et al., 2008; Williams & Ericsson, 2008). Alternatively, this finding may suggest that coaching and judging qualifications are not suitable methods of classifying experts and novices. Therefore, future research could focus on comparisons of number of years experience within a sport as potential discriminators of expert performance (Ward et al., 2008). Research investigating discriminatory tasks, along with differing levels of expertise measured through experience in sport and qualification would enable researchers to determine which methods are most beneficial for developing perceptual training programmes.

Secondly, this thesis only focused on one mechanism (visual search) that underpins the effectiveness of the perceptual training programme. The research programme therefore made no attempt to measure the knowledge of the coaches and judges from baseline to the post-test and retention test. This method was insufficient in enabling empirical conclusions that the perceptual training programme enhanced knowledge. Therefore inferences that knowledge was increased which enabled the coaches and judges to become more expert like in their judgment formation cannot be confirmed. It is therefore recommended that future research into perceptual training measures the changes in knowledge as a result of the perceptual training programme in addition to changes in visual search. This would enable a more thorough understanding of the other mechanisms that underpin success of perceptual training programmes.

Further to assessing changes in knowledge, it may also be appropriate to assess changes in specific types of knowledge in order to understand how they might change as a result of perceptual training programmes. This would be further enhanced through studies in sport clarifying the meaning of different types of knowledge as previous research has referred to declarative knowledge and technical knowledge as similar concepts and as such, inconsistencies in terminology need to be reduced. Additionally, given the differences in the roles performed by coaches and judges, it may be evident for example, that a judge has more declarative knowledge than a coach, and therefore assessing knowledge base may determine the focus of the training programme that is required to enable enhanced judgment formation.

In addition to the mechanisms that underpin expertise, the training programme itself also requires validation. For example this thesis used a perceptual training programme that included elements of guided discovery and explicit instruction, whereas other researchers have recommended more implicit based programmes (Poulter et al., 2005). Therefore, a comparison between implicit and explicit training of coaches and judges may also prove valuable in gaining an understanding of the best methods to train this population. A more implicit based training programme may help judges and coaches perform whilst under pressure given the positive findings in the motor skills literature based on implicit training and pressure stated by Jackson and Farrow (2005). In addition, the perceptual training programme utilised in this thesis was specifically designed for the handspring vault. However, the application and transfer of similar types of programmes to other types of vault and indeed other apparatus in gymnastics needs to be investigated. An alternative to producing a training programme for every move based on individual apparatus would be to produce more generalised sport training programmes. For example, handsprings can also be performed in floor routines, and on the beam, thus the training videos could be adapted to suit a variety of judging scenarios.

Furthermore, and perhaps most exciting given the nature of other work in this area, it would be interesting to establish the importance of the visual cues identified in this research through the use of occlusion paradigms. Specifically, it would be interesting to assess whether occluding the shoulders and torso through the five phases of the vault resulted in reduced performance by coaches and judges suggesting that central vision is most important to the judging process. Alternatively if judges are able to perform well with these cues occluded it would further validate the suggestions put forward in the discussion that experts use peripheral cues to aid judgment formation. It would also be interesting to analyse the most important phases of the vault. A temporal occlusion technique would allow researchers to establish, when occluded, the stages that contribute most to the decision making process. This could further cut down the information processing loads of novice coaches and judges and would give evidence of the important of anticipation when judging the handspring vault.

With advances in eye-tracking and the introduction in recent years of more mobile systems and more advanced software, it seems that future data will be able to be assessed in the field rather than in laboratory situations. It is a very exciting time to be involved in eye-tracking and with the relatively new introduction of 3 dimensional calibration it seems that such field testing would be a real benefit to many applied researchers, enabling a new wave of more ecologically valid research. Specifically, being able to wear an eye-tracker whilst moving around will address some of the concerns that ecological psychologists have in terms of separating perception and action. Furthermore, with advances in the analysis software the frame-by-frame nature of the analysis should become automatic which will allow researchers more opportunities to collect data from larger cohorts of participants.

It is recommended that future research aims to examine the use of perceptual programmes for training coaching and judging expertise in a variety of sports. This thesis suggest that perceptual training is useful for training decision making by coaches and judges in gymnastics, but this needs to be validated by investigating the usefulness of perceptual training in other sports. Indeed, the usefulness of a coach and judges training programme for gymnasts and other sports performers should also be considered given that sport performers need to be aware of how they are being assessed. More specifically, investigating the use of perceptual training in other sports will allow researchers to assess the usefulness of collecting expert visual search and declarative knowledge data for training purposes.

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APPENDIX 1: CONSENT FORM

DATE

CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary.
2. I am free to withdraw from the project at any time without any disadvantage.
3. The raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.
4. The results of the project may be published but my anonymity will be preserved.

I agree to take part in this project.

Signature of participant .... Date: …………

Age: ……….

Number of years Judging / Coaching (please delete as appropriate): ……………………..

Coaching / Judging level (e.g., assistant club coach): ………………. ……………………..

Signature of researcher …………………………… Date: …………

APPENDIX 2: INFORMATION SHEET (STUDY 1)

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

This will examine the consistency of visual search patterns across 10 vaults.

What Type of Participants are Needed?

The participants required are coaches and judges in gymnastics with assistant club coach or club judge qualifications and above.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to watch 25 video clips of vaults whilst wearing an ASL eye-tracker. You will be asked to score each vault out of 10 based on the criteria given to you and give this score verbally within 5 seconds of each clip finishing.

You will then be asked to watch a similar set of clips in approximately 4 weeks.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Your visual search patterns and you score given for each vault will be collected. They will also be recorded when you re-watch the similar video in 4 weeks. The visual search patterns will then be compared.

Results of this study may be published.
The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

What if Participants have any Questions?
If you have any questions about our project, either now or in the future, please feel free to contact either:-

Jennifer Page
Department of Sport and Exercise Sciences
University Telephone Number: 01244 375444 ex: 3560

Dr Moira Lafferty
Department of Sport and Exercise Sciences
University Telephone Number: 01244 375444 ex:3438

APPENDIX 3: SCORING CRITERIA

1st FLIGHT Legs separated > 0.3 Knees bent > 0.5 Poor Technique : hip angle > 0.3 :arch in back > 0.3	REPULSION Poor Technique : Shoulder angle > 0.3 Arms bent > 0.5 Failure to pass through vertical > 0.3
2nd FLIGHT Legs : separated > 0.3 Knees bent > 0.5 Lack of stretch > 0.3 Lack of height > 0.5	LANDING Legs apart 0.1 Slight hop adj. of feet 0.1 Steps each (to a max of 7) 0.1 Very large step or hop (max 7) 0.3 Deep squat 0.5 Extra arm swings 0.1 Trunk movements for balance >0.3 Poor body posture >0.3 Direction : 1 foot out of zone 0.1 2 feet out of zone 0.3 Insufficient length >0.5 Insufficient Dynamics >0.5
	INVALID VAULTS **Failure to use safety collar for R/O vaults Spotting Assistance** **Touch apparatus but no vault** **Failure to land feet first** **No Touch on the vault table** **ALL VOID**

APPENDIX 4: COEFFICIENT OF VARIATION CALCULATION

SD_{diff} was calculated by using the difference in the measurement between the test occasions for each participant, and then calculating the mean difference and standard deviation of the differences (SD_{diff}). The coefficient of variation (CV) was determined from 100 times the log transformed variable:

$$CV = 100\,(e^{s/100} - 100)$$

Where s is the typical error: ($SD_{diff}/\sqrt{2}$)

APPENDIX 5: STUDY 1 SPSS OUTPUT

Wilcoxon Signed Ranks Test

Rank

		N	Mean Rank	Sum of Ranks
mean number of fixations - mean number of fixations	Negative Ranks	8(a)	5.81	46.50
	Positive Ranks	4(b)	7.88	31.50
	Ties	0(c)		
	Total	12		
mean duration - mean duration	Negative Ranks	6(d)	9.33	56.00
	Positive Ranks	6(e)	3.67	22.00
	Ties	0(f)		
	Total	12		
mean number of areas fixated - mean number of areas fixated	Negative Ranks	6(g)	6.50	39.00
	Positive Ranks	5(h)	5.40	27.00
	Ties	1(i)		
	Total	12		

a mean number of fixations < mean number of fixations
b mean number of fixations > mean number of fixations
c mean number of fixations = mean number of fixations
d mean duration < mean duration
e mean duration > mean duration
f mean duration = mean duration
g mean number of areas fixated < mean number of areas fixated
h mean number of areas fixated > mean number of areas fixated
i mean number of areas fixated = mean number of areas fixated

Test Statistics(b)

	mean number of fixations - mean number of fixations	mean duration - mean duration	mean number of areas fixated - mean number of areas fixated
Z	-.591(a)	-1.334(a)	-.537(a)
Asymp. Sig. (2-tailed)	.554	.182	.591

a Based on positive ranks.
b Wilcoxon Signed Ranks Test

Logistic Regression – Number of fixations

```
[DataSet2] N:\study 1\three variables.sav
```

Case Processing Summary

Unweighted Cases(a)		N	Percent
Selected Cases	Included in Analysis	24	100.0
	Missing Cases	0	.0
	Total	24	100.0
Unselected Cases		0	.0
Total		24	100.0

a If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
trial1	0
trial2	1

Block 0: Beginning Block

Classification Table(a,b)

Observed			Predicted		
			trial		Percentage Correct
			trial1	trial2	trial1
Step 0	trial	trial1	0	12	.0
		trial2	0	12	100.0
	Overall Percentage				50.0

a Constant is included in the model.
b The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	.000	.408	.000	1	1.000	1.000

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	number	.178	1	.673
	Overall Statistics		.178	1	.673

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	.178	1	.673
	Block	.178	1	.673
	Model	.178	1	.673

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	33.093(a)	.007	.010

a Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.504	8	.175

Classification Table(a)

Observed			Predicted		
			trial		Percentage Correct
			trial1	trial2	trial1
Step 1	trial	trial1	7	5	58.3
		trial2	4	8	66.7
	Overall Percentage				62.5

a The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Step 1(a)	number	-.405	.964	.176	1	.675	.667	.101	4.412
	Constant	.748	1.827	.167	1	.682	2.112		

a Variable(s) entered on step 1: number.

Logistic Regression – Fixation duration

Case Processing Summary

Unweighted Cases(a)		N	Percent
Selected Cases	Included in Analysis	24	100.0
	Missing Cases	0	.0
	Total	24	100.0
Unselected Cases		0	.0
Total		24	100.0

a If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
trial1	0
trial2	1

Block 0: Beginning Block

Classification Table(a,b)

Observed			Predicted		
			trial		Percentage Correct
			trial1	trial2	trial1
Step 0	trial	trial1	0	12	.0
		trial2	0	12	100.0
	Overall Percentage				50.0

a Constant is included in the model.
b The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
		Lower	Upper	Lower	Upper	Lower	Upper
Step 0	Constant	.000	.408	.000	1	1.000	1.000

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	duration	.994	1	.319
	Overall Statistics		.994	1	.319

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	1.010	1	.315
	Block	1.010	1	.315
	Model	1.010	1	.315

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	32.261(a)	.041	.055

a Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.992	8	.152

Classification Table(a)

Observed			Predicted		
			trial		Percentage Correct
			trial1	trial2	trial1
Step 1	trial	trial1	7	5	58.3
		trial2	5	7	58.3
	Overall Percentage				58.3

a The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Step 1(a)	duration	-.744	.759	.962	1	.327	.475	.107	2.103
	Constant	6.255	6.392	.958	1	.328	520.748		

a Variable(s) entered on step 1: duration.

Logistic Regression – Number of areas fixated

```
[DataSet2] N:\study 1\three variables.sav
```

Case Processing Summary

Unweighted Cases(a)		N	Percent
Selected Cases	Included in Analysis	24	100.0
	Missing Cases	0	.0
	Total	24	100.0
Unselected Cases		0	.0
Total		24	100.0

a If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
trial1	0
trial2	1

Block 0: Beginning Block

Classification Table(a,b)

Observed			Predicted		
			trial		Percentage Correct
			trial1	trial2	trial1
Step 0	trial	trial1	0	12	.0
		trial2	0	12	100.0
	Overall Percentage				50.0

a Constant is included in the model.
b The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
		Lower	Upper	Lower	Upper	Lower	Upper
Step 0	Constant	.000	.408	.000	1	1.000	1.000

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	areas	.000	1	.990
	Overall Statistics		.000	1	.990

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	.000	1	.990
	Block	.000	1	.990
	Model	.000	1	.990

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	33.271(a)	.000	.000

a Estimation terminated at iteration number 2 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	9.337	8	.315

Classification Table(a)

Observed			Predicted		
			trial		Percentage Correct
			trial1	trial2	trial1
Step 1	trial	trial1	7	5	58.3
		trial2	7	5	41.7
	Overall Percentage				50.0

a The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Step 1(a)	areas	-.015	1.202	.000	1	.990	.985	.093	10.390
	Constant	.038	3.075	.000	1	.990	1.038		

a Variable(s) entered on step 1: areas.

APPENDIX 6: INFORMATION SHEET (STUDY 2)

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

This project will investigate what the differences between what expert and novice coaches and judges are looking at through use of eye-tracking.

What Type of Participants are Needed?

The participants required are coaches and judges in gymnastics qualified to women's artistic assistant club coach and / or club judge level for the novice level participants and women's artistic high performance coach and / or national judge level for the expert level participants

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to watch 11 video clips of vaults whilst wearing an ASL eye-tracker. You will be asked to score each vault out of 10 based on the criteria given to you and give this score verbally within 5 seconds of each clip finishing.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Your visual search patterns and you score given for each vault will be collected.

Results of this study may be published.

The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

What if Participants have any Questions?

If you have any questions about the project, either now or in the future, please feel free to contact either:-

Jennifer Page
Department of Sport and Exercise Sciences
University Telephone Number: 01244 511422

Dr Moira Lafferty
Department of Sport and Exercise Sciences
University Telephone Number: 01244 513438

APPENDIX 7:STUDY 2 SPSS OUTPUT

Tests of Normality

	exp	Kolmogorov-Smirnov(a) Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
mean number of fixations	novice	.330	12	.001	.798	12	.009
	expert	.280	8	.065	.924	8	.465
mean duration	novice	.186	12	.200(*)	.934	12	.427
	expert	.163	8	.200(*)	.966	8	.864
mean score	novice	.121	12	.200(*)	.988	12	.999
	expert	.311	8	.022	.754	8	.009
mean number of areas fixated on	novice	.272	12	.015	.906	12	.192
	expert	.167	8	.200(*)	.978	8	.950
headt1	novice	.174	12	.200(*)	.903	12	.173
	expert	.217	8	.200(*)	.912	8	.368
torsot1	novice	.131	12	.200(*)	.922	12	.301
	expert	.174	8	.200(*)	.956	8	.771
hipt1	novice	.307	12	.003	.725	12	.001
	expert	.119	8	.200(*)	.990	8	.995
legt1	novice	.360	12	.000	.593	12	.000
	expert	.246	8	.166	.799	8	.028
armt1	novice	.261	12	.023	.812	12	.013
	expert	.323	8	.014	.740	8	.006
frontt1	novice	.301	12	.004	.771	12	.005
	expert	.429	8	.000	.547	8	.000
behindt1	novice	.283	12	.009	.671	12	.000
	expert	.222	8	.200(*)	.854	8	.104
othert1	novice	.213	12	.140	.871	12	.068
	expert	.273	8	.081	.798	8	.027

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

General Linear Model

Between-Subjects Factors

Descriptive Statistics

	exp	Mean	Std. Deviation	N
mean number of fixations	novice	3.8917	.98945	12
	expert	6.5750	.81723	8
	Total	4.9650	1.62230	20
mean duration	novice	159.4917	19.04787	12
	expert	200.6350	20.17846	8
	Total	175.9490	28.06622	20
mean score	novice	6.8146	.68742	12
	expert	7.1225	.70196	8
	Total	6.9378	.69215	20
mean number of areas fixated on	novice	2.4167	.43866	12
	expert	3.1250	.50356	8
	Total	2.7000	.57583	20

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	Pillai's Trace	.997	1191.295[b]	4.000	15.000	.000	.997	4765.179	1.000
	Wilks' Lambda	.003	1191.295[b]	4.000	15.000	.000	.997	4765.179	1.000
	Hotelling's Trace	317.679	1191.295[b]	4.000	15.000	.000	.997	4765.179	1.000
	Roy's Largest Root	317.679	1191.295[b]	4.000	15.000	.000	.997	4765.179	1.000
exp	Pillai's Trace	.722	9.738[b]	4.000	15.000	.000	.722	38.952	.995
	Wilks' Lambda	.278	9.738[b]	4.000	15.000	.000	.722	38.952	.995
	Hotelling's Trace	2.597	9.738[b]	4.000	15.000	.000	.722	38.952	.995
	Roy's Largest Root	2.597	9.738[b]	4.000	15.000	.000	.722	38.952	.995

a. Computed using alpha = .05

b. Exact statistic

c. Design: Intercept+exp

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	mean number of fixations	34.561[b]	1	34.561	40.281	.000	.691	40.281	1.000
	mean duration	8125.315[c]	1	8125.315	21.379	.000	.543	21.379	.992
	mean score	.455[d]	1	.455	.947	.343	.050	.947	.152
	mean number of areas fixated on	2.408[e]	1	2.408	11.139	.004	.382	11.139	.884
Intercept	mean number of fixations	525.845	1	525.845	612.867	.000	.971	612.867	1.000
	mean duration	622517.837	1	622517.837	1637.911	.000	.989	1637.911	1.000
	mean score	932.363	1	932.363	1940.789	.000	.991	1940.789	1.000
	mean number of areas fixated on	147.408	1	147.408	681.803	.000	.974	681.803	1.000
exp	mean number of fixations	34.561	1	34.561	40.281	.000	.691	40.281	1.000
	mean duration	8125.315	1	8125.315	21.379	.000	.543	21.379	.992
	mean score	.455	1	.455	.947	.343	.050	.947	.152
	mean number of areas fixated on	2.408	1	2.408	11.139	.004	.382	11.139	.884
Error	mean number of fixations	15.444	18	.858					
	mean duration	6841.226	18	380.068					
	mean score	8.647	18	.480					
	mean number of areas fixated on	3.892	18	.216					
Total	mean number of fixations	543.030	20						
	mean duration	634127.552	20						
	mean score	971.750	20						
	mean number of areas fixated on	152.100	20						
Corrected Total	mean number of fixations	50.006	19						
	mean duration	14966.540	19						
	mean score	9.102	19						
	mean number of areas fixated on	6.300	19						

a. Computed using alpha = .05

b. R Squared = .691 (Adjusted R Squared = .674)

c. R Squared = .543 (Adjusted R Squared = .518)

d. R Squared = .050 (Adjusted R Squared = -.003)

e. R Squared = .382 (Adjusted R Squared = .348)

Mann-Whitney Test

Ranks

	exp	N	Mean Rank	Sum of Ranks
headt1	novice	12	8.75	105.00
	expert	8	13.13	105.00
	Total	20		
torsot1	novice	12	12.08	145.00
	expert	8	8.13	65.00
	Total	20		
hipt1	novice	12	9.50	114.00
	expert	8	12.00	96.00
	Total	20		
legt1	novice	12	9.08	109.00
	expert	8	12.63	101.00
	Total	20		
armt1	novice	12	12.50	150.00
	expert	8	7.50	60.00
	Total	20		
frontt1	novice	12	10.38	124.50
	expert	8	10.69	85.50
	Total	20		
behindt1	novice	12	10.46	125.50
	expert	8	10.56	84.50
	Total	20		

a Mann-Whitney Test cannot be performed on empty groups.

Test Statistics(b)

	headt1	torsot1	hipt1	legt1	armt1	frontt1	behindt1
Mann-Whitney U	27.000	29.000	36.000	31.000	24.000	46.500	47.500
Wilcoxon W	105.000	65.000	114.000	109.000	60.000	124.500	125.500
Z	-1.620	-1.466	-.926	-1.436	-1.913	-.117	-.040
Asymp. Sig. (2-tailed)	.105	.143	.355	.151	.056	.907	.968
Exact Sig. [2*(1-tailed Sig.)]	.115(a)	.157(a)	.384(a)	.208(a)	.069(a)	.910(a)	.970(a)

a Not corrected for ties.
b Grouping Variable: exp

APPENDIX 8: INFORMATION SHEET (STUDY 3)

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

This project will investigate what expert coaches and judges are looking at through use of eye-tracking and interviews.

What Type of Participants are Needed?

The participants required are coaches and judges in gymnastics with senior club coach or regional club judge qualifications and above.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to watch 11 video clips of vaults whilst wearing an ASL eye-tracker. You will be asked to score each vault out of 10 based on the criteria given to you and give this score verbally within 5 seconds of each clip finishing.

You will then be asked to watch a video of 11 vaults and asked questions relating to the information used to get the score and what you were looking at during each phase of the vault.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Your visual search patterns and you score given for each vault will be collected.
The interviews will be recorded using an audio recorder and will be transcribed verbatim.

Results of this study may be published.
The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

What if Participants have any Questions?

If you have any questions about the project, either now or in the future, please feel free to contact either:-

Jennifer Page
Department of Sport and Exercise Sciences
University Telephone Number: 01244 511422

Dr Moira Lafferty
Department of Sport and Exercise Sciences
University Telephone Number: 01244 513438

APPENDIX 9: INTERVIEW QUESTIONS

What information did you use to help formulate the score of the vault?

Where did you look to get this information?

Why did you look there?

What information did you use to help formulate the score during the run up?

Where did you look to get this information?

Why did you look there?

What information did you use to help formulate the score during the hurdle step?

Where did you look to get this information?

Why did you look there?

What information did you use to help formulate the score during the first flight phase?

Where did you look to get this information?

Why did you look there?

What information did you use to help formulate the score during the second flight phase?

Where did you look to get this information?

Why did you look there?

What information did you use to help formulate the score during the landing?

Where did you look to get this information?

Why did you look there?

** repeated for all ten vaults

APPENDIX 10: EXAMPLE OF INTERVIEW TRANSCRIPT

Participant

Role:

Can you tell me what you are actually looking for when you're analysing the handspring vault?

Well the first thing that I look for is the run-up (um) because generally a gymnast who cannot run can't get the dynamics in the run for example of their heels are low to the floor we know that the dynamics of the handspring vault is going to be very slow umm and we also predict that they'll bend their arms in flight, their shape won't be straight so the first thing I look for is um how efficient their run is um in terms of whether they're on their toes, whether their shoulders are forward um also as soon as they hit the board I am looking at their arm position and the position of their shoulders also um their heels and how fast, how fast they move um out of the pike shape, the bent shape on the board if they flick to a straight shape um again if they show a handstand on the top and whether their shoulders are forward again that all (er) matters in terms of the repulsion, the push off, if their arms are bent say for example on the vault they won't get the high push off and we're looking for a nice long flight in the post flight phase um and to ensure that it goes up. Some gymnasts show a handstand, then they (d) they show no push off and just fall you know off the vault rather than the push off um and then also their knees on landing, if they're landing in a deep squat, then they haven't got the um efficient push off the vault.

OK, so would you say that any one phase of the vault was more important than the other?

Um (pause) that's a hard question really, (th) the take off position um and the pre-flight is important in terms of the shape and how fast the heels are moving um and then also the (rep) repulsion phase because if they've got a strong push off that determines how long and how high the post flight is and the post flight is quite an important phase um and because that's .. it's like a pre-requisite for their landing position and whether that's going to be successful or not.

OK

So the pre-flight and the post flight I'd say.

OK are you ready to have a look at the first vault?

Yes.

OK You should see it now, vault 1

Again quite a slow vault there, she came off quite piked and you can see straight away that it was going to be very slow so she'd lose quite a lots of marks on dynamics there um little push off, little flight just sort of came on and came off there was no flight at any point really.

OK Can you take me through it?

Yeah sure.

You go that way (referring to VHS) –
What are you looking at here during the run up?

Um again not fast off her feet, quite slow with her heels. The takes off's quite good although really her shoulders should be slightly further back there you can hear, see here that the feet are still pointing down towards the board really they should .. start moving quite quickly so that when she comes on to the vault if you can see her hip angles piked it should be here (referring to straight body line) um therefore she doesn't get her handstand phase, that's supposedly the handstand phase – her arms are bent in support and in the pike position, there's no straight shape there, also really she hitting the front of the vault – she needs to be sort of further this way (referring to the back of the vault). Again because of the position that she was on the board she couldn't get the flight to move closer to the end.

So in terms of how piked she is, where are you getting that type of information from?

How heel, how fast her heels are moving from the board as soon as she hits that board I'm looking at here (referring to the heel) and watching this action

The heel

Yeah, the heel, it's all about how quickly the heel moves from there upwards um and then here really the push of should go towards this way (referring to diagonal towards the ceiling) you know sort of like a rocket position but she's coming over quite flat, and coming straight to the floor, this should be longer um and she should push further away from the vault. One of the judging criteria is how um far they are away from the vault un and the last code there use to be a line and if she didn't land far um far .. further away from that line she would lose quite a lot of marks so again that's something quite distinctive that we look for.

Shall we keep going to the next one?

Yeah, yeah, if you are happy about that one – do you have anything else to say about that one?

No.

No OK

Where did you learn all your information about the pike position, who told you about that?

Um well my background, as well as a judge I'm a coach um so we did it on the coaching courses and also from my knowledge about efficiency of the handspring vault we know that a vault that's piked is very slow in dynamics a vault that comes on very straight with a flatter hip angle is much higher and faster.

Right so if I take you to the next one – this is vault 2

Um so hers is a lot faster in comparison to the, to the other gymnast, the run ups a lot faster.

Where are you getting the information about how quick it is?

Just because again I'm looking at her heels and how quickly they are moving off the floor um and you can see from her position that she's moving quite quickly as well and the position of her shoulders. That's an excellent position um because her shoulders are behind her feet and her arms are up there.

On the board?

Yeah, and then she um is faster with her heels although it's not particularly straight at that point um she's a lot faster than the other gymnast again her lines is a lot better it's a much more of a straighter line now and the position of the shoulders with regards to her hand position. She gets quite a strong push off because there's no bent arms. Expect her to lift a little bit more off here and another thing we look um at is the shape and the size of the gymnast like I expect her to be a bit more efficient particularly in the run up and the push off because she is very slight and so that's another factor really, keeps a nice straight shape all the way through the flight um she didn't really get as much push off as she needed to, her shoulders are still here need to be a little bit more forwards and that's why she's having a bit of a problem with her landing a little bit deep, she's having to work hard to bring those shoulders forwards. Um but generally quite a nice vault, nice straight alignment.

OK anything else?

No,

OK

Am I taking too long?

No definitely not, this is Vault 3

Um again quite a slight little gymnast you can see that she has got a lot of, lot of power in her legs, her heels are moving quickly off the floor, she's using her arms more efficiently.

So are arms something you generally look for in a run up?

Yeah especially more on her than the others um therefore she must be a lot more efficient using her arms to help her in the run up. A good swing of the arms there really trying to get the fight on to the board again nice position shoulders are behind the feet , again she kept nice and straight um she's' actually, you can see that she got quite a good push off from the board um in terms of where she landed on the vault again the alignment she's straight, what I did notice about this gymnast was that she bent her arms which is what let her down really, she's very efficient with her heels, very fast off the board, it's just her arms bent in support which then doesn't give her a sufficient push off however because she's very tight in the middle and her legs which is keeping the alignment of this phase um she can keep that straight shape therefore it looks quite good. Landing is lovely she's coming down in a straight shape, her shoulders um you can tell she got quite a good push off –um although she didn't get, she didn't have her arms straight – you can see that she's quite strong, she's got strong upper body because she got the push off and her shoulders are in the right position for landing, so she can just bring them forward and she's landed, however, it's hard for her because she's landed on a horrible mat (laughs). Yeah so that one's quite a nice one, just the bent arms in the support phase.

OK thank you – Vault 4

That was much better, um she seemed to come on a lot faster so she was moving her heels quickly off the floor you can see hers arms are quite straight so she loses the efficiency there um I'm talking about coaching here.

That's alright

Yeah so that's' probably letting her down really, her arms are quite straight throughout that phase, then good power with her arms here using it to push off to bring the flight on to the board, that was a lot better there, the shoulder alignment was much better in terms of the heels, there weren't as forward as the last vault that she did again comes on quite straight however didn't flick her heels at that point she was doing it she seemed to move her feet quite fast but she was doing it through her bottom rather than taking her heels up so gain she's not really getting handstand, her arms are a little bit bent and her shoulders are slightly forward, the shoulders are slightly forward and the not going to get an efficient push off sometimes that's a very hard to see, sometimes all we see as judges is whether they bent their arms or not, it's hard to see exactly where their shoulders are if they are here a she not going to get a good push off, the little bend that she had she got a good push off tight in a straight line then she came down here with her shoulders a little bit more forward than last time which is why the landing is much better, probably a bit too much of a snap off there in terms of the body shape which is why she's having to step forward there needs to be just like a slight movements, very hard to get that balance you want to get the push of here but you need to control it in the tummy so that the shoulders so not over rotate which then forces you to step forward which adds further deduction to the performance.

So in the landing phase then, where in the body are you looking for that information?

Um again it's the push off and .. and whether it goes up here or whether it just goes down flat if it comes down flat her shoulders are going to be very far behind her feet then that's' not going to be efficient, efficient performance and so you need to push off and keep it quite straight and she's coming down with her shoulders slightly before her heels, if it's too far away they're just going to sort of plonk flat on the floor so she .. she needs to push off and her shoulders just stay very close .. close behind her feet.

OK

Yeah so looking at her shoulder position in relation to her feet.

Vault 5

Again quite slow dynamics very little flight again because of her run up she's not getting her heels fast enough off the floor she needs to get right up on those toes um the arms are coming a little bit wide which makes the run up less efficient than one that's or of is very close to the body with the elbows close to the body. Quite a good position as she is coming on, again very slow with the heels, what should happen in a soon as she's on the board um all she's really interested in is getting her hand on the vault, from a coaching point of view we say that's she's diving onto the vault, whereas a gymnast should show extension, the come on to the vault late a lot of gymnast makes that mistake they just run up and put their hands on and their feet are still on the board, you need a flick of the heels so she's coming on to the vault far too soon in ration to where her feet up, here feet should be here for a extended shape. Here that is supposed to be a handstand position and you can see that the shoulders are over her hands and therefore you're not going to get a efficient push off, you can't push off its physically impossible unless you're a super woman, the shoulders need to be in line with the wrist so does the hip and the feet so we know from that that, we can almost predict what is going to happening the post flight in terms of the length, all she is doing is coming down when the flight should be pushing off, rocketing into the air which then effects her landing position and we can see that she um stapes out the reason why we can see that is because it is quite flat it just coming down, there's no push off so there a lot of rotation through the shoulders like that, which is why they come too far forwards and she steps forward. Quite a large step.

Happy with that?

Yeah, thank you.

Vault 6

That one is much better you can see her alignment is very nice and she's very tight throughout, again nice fast heels arms are aren't as efficient as they should be she's gets a strong push off from there again another thing we look at is where they take off from and how long that hurdle phase is and hers is quite long really showing lots of power excellent position in terms .. terms of the shoulders coming through.

On the Board?

Yeah um she is not coming on and plonking um she is showing more flight within the .. the air her arms come down pretty .. pretty late although she could do with moving, moving these heels a little faster. Um again because she hasn't moved her feet quick enough from the board we know that this isn't going to be a handstand .. handstand position and we know that there is going to be a lot of rotation through the shoulders which um means that she'll have to bring them forward on the push off phase therefore she won't get the efficient push of that she required however she keeps nice and straight with tension in the tummy she tries nice and hard to get the push off and move away from the vault and comes down nice and straight with the shoulders just behind just following her feet gradually she comes down and she's fine and she's managed to stabilise the landing. The best ones she's done.

Laughs, thank you, vault 7

That's one was much faster you could see that she was a lot quicker in her run up a lot more efficient she was moving her feet faster off, faster off the floor the shoulders were in a good position to keep her moving forward, again, her arms are letting her down, just slowing her down a little bit however her feet are going fast and that's helping her this time she gets quite a good hurdle step, quite long within the phase again fast again the shoulders um in a good position so when the feet hit the board they should .. should be behind arms are coming through nicely, she spent more time in the flight phase um you can see that because she's much straight, previously she has been much piked and plonked her hands on therefore this, in this phase she can adjust her shape and get it nice and straight whereas when she was very slow with her feet slow of the board she's got time to put her hands on the bard and then she thinks about her feet then she can think about her feet and adjust her shape before she comes on to the board which you need to do in order to get a good, an effective repulsion, again, because her feet haven't moved fast enough and there is too much rotation through the shoulders from here to there rather than coming off then coming down onto the vault, shoulders are coming forwards over her hands again she shows not in an exact handstand phase because her feet have not moved quick enough within an optimal handspring vault however off the board where she is going to struggle to get the height and the flight required um within an optimal handspring vault however she keep a lot tight squeezes the tummy, the shoulders are quite far behind the feet therefore she has got to work faster and got to really squeeze those muscles to stabilise the landing and that's why she's got to take a step as well, just to stop the rotation through the shoulders, but that was much better as there was a lot more power within the first phase.

OK, vault 8

Again from the run up the whole dynamics of the vault is very slow um and gain it's because of the run up her heels are very flat and the upper-body position is quite awkward with her bottom sticking out and shoulders forward really she should try and move her shoulders back a little bit. Again her arms aren't efficient with .. with quite a lot of movement, with the elbows coming out to the side of the body rather than staying close. The shoulders are forward over her feet, therefore we know she is going to struggle with the initial phase mind you that's quite hard to see as a judge, you can comment on it now because it's obvious but that's' quite hard to catch that particularly with how fast it is going and that is why um I concentrate on the feet because that helps me, how quickly her feet move determines the success of the vault for me. Again she hasn't moved her feet and that is very piked um feet apart as will is gonna cause problems in terms of efficiency of the next phases arms are very bent um and she's just dived and plonked her hands on the vault rather than showing the flight and extension and coming on to the vault quite late you can see that because she hit the um the front of the vault as well bent those are really bent arms the head close there although she stays quite tight in her upper body but again her feet aren't in a vertical position therefore that's they the coach has put a hand there because she is very close um and she hasn't got a strong push off because of her bent arms therefore she's coming quite close to the vault on the way down, the landings quite good, her shoulders are in relatively good position as they are just slightly behind the feet which is where they need to be, however, she's shown no flight and no length within the post-flight, post-flight phase, it was over very quickly, however her shoulders were very good in this phase and she has pushed off um.

In the post flight phase

Yeah the post-flight phase, which is why she's got a stable landing.

OK Vault 9

This one's interesting because she stays nice and straight and she seems to get quite a good run up not as fast as the others have been because of the way she plonking her heels down, she's not as high up on her toes as she has been previously she gets a good swing which drives this hurdle phase, creates a lot of power for the push off from the board, her shoulders are in a very good position there (on the board) she stays very nice and tight, she's got strong tummy muscles, she's squeezing them. She could have moved her heels a little bit faster because she's not in that handstand phase the shoulders slightly forward so she's not going to get a brilliant push off and that gonna show that she's gonna cause a lot of rotation here um which I know um affects their landing and whether they take a step in landing. Um it's almost as if gravity has taken over and she just coming down, like a you know when you chuck and apple in the air and its comes straight down it's a bit like that whereas she should be pushing off and coming away from the vault, she's just going to go down just letting gravity bring her down, she stays quite straight which helps her a lot but as you can see her shoulders are far behind far away from her feet uh which is why she has a problem with her landing and has to bend her knees to try and bring her shoulders forward, other than that just results in a deep squat, she really has to try and push her shoulders forward to try and stabilise it and then she has to take a step to bring her shoulders back in line.

OK Happy with that one?

Yeah.

Vault 10, this is the last one

Quite a good run up but very slow off the board here you can see that she's on her toes, feet are a little bit low, her shoulders are in quite a good position driving her forward, hurdles excellent, get lots of height, gets a good push off from the floor which allows her to hit the board, excellent position there with her shoulders uh allowing her to push her feet nice and nice fast off the board, feet need to be a little bit quicker hence the pike phase that she has got um not a bad shape heels need to come a little bit higher that's because she hasn't; pushed off the board, shoulder are a little bit far forward therefore she's not going to get a brilliant push off which is why um she just, she has a very short um a not a long post flight phase, shoulders are quite god, quite close to where her feet are, and then because she hasn't pushed off in this post flight phase she's just let he feet go down, she's having to take a step and the shoulders have over-rotated because the shoulders have gone from here to there, when it should have gone up and then come down over here like a projectile.

OK so in terms of the handspring vault in general you talked a lot about the different phases. That run up phase … can you pin point what you are looking for?

Um how .. how quickly the feet, um to be honest I concentrate on the feet for the whole phase looking at what's happening, how fast they are moving off the floor um I look at when she jumps on the board and how quickly they move up to the handstand phase so I just concentrate on the feet really.

Ok, so in the post flight phase does your attention shift to other parts of the body then?

Yeah it shifts to um her shoulders um because we're looking for quite a high and a long phase so I concentrate on where her shoulders are so it sort of moves as soon as …. I watch her feet until she gets to handstand I look to see if there's a handstand position in the body and then and then I look at what's the pathway of her shoulders.
OK Thank you very much.

APPENDIX 11: INFORMATION SHEET (STUDY 4)

Please read this information sheet before deciding whether or not you would like to participate in this study.

What is the aim of the project?

It will examine the effect of watching specific videos on decision making.

What types of participants are needed?

The participants required are British Gymnastics judges and coaches (women's artistic gymnastics).

What will I be asked to do?

To evaluate the effectiveness of a DVD, you will be asked to watch and judge (whilst wearing an eye camera) a video containing a series of handspring vaults on 4 occasions (based at the University of Portsmouth). Each session will last for approximately 20 minutes and will be spread over 3 months. Between each of the 4 sessions, you will be asked to watch a short training DVD at home. Parking will be arranged for you on the campus.

Can I change my mind and withdraw from the project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What data or information will be collected?

Your visual search patterns will be recorded using a video camera and the score given for each vault will be collected on paper.

Results of this study may be published.

The data collected will be securely stored in such a way that only the author (Miss Jenny Page) be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

What if I have any questions?

If you have any questions about the project, either now or in the future, please feel free to contact me:-

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PO1 2ER, UK
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If you decide that you might want to participate in this study, I would like to thank you for your time, and ask you to return the attached form to the above address. I will then contact you at a time that is convenient to you. If you decide not to take part, there will be no disadvantage to you of any kind and I would like to thank you for considering my request.

APPENDIX 12: EXAMPLE OF SOCIAL VALIDATION INTERVIEW

Can you tell me how useful the training DVD was for you in your role as a coach?

The first part, the vaults with the circles, I found that the most useful bit because that was more obvious like what to look at because with the words it was a bit repetitive when watching like having to look at them each time sort of thing, ,

What information do you think the circles provided you?

We it said that it was where the experts or like the more highly trained coaches and judges looked so I figured that that was where to look to see the um where you're going to get the most information from about the quality of the performances,

So would you recommend the intervention to others?

Um, yeah um definitely especially if it was on all different pieces rather than just vault but yeah definitely,

How do you think it might help them?

Um I don't know really but within certain moves it might help you like you might not realise that they're always in a certain body shape and they like, I don't know really, you know like when you're watching a move you might not know that all experts make a certain body shape and that you're gymnasts aren't making that shape so you're more likely to notice that if you can see where, I don't really know (laughs)

Um the bit at the beginning with words is more useful for people that haven't, that are like newer to gym um like parents or … that come in and coach or judge if they haven't done gym before they don't know what to look at whereas if you've done gym before then you're used to coaches giving your information about your performance you're better, you know more about what to look for in a vault or in any gym move really

Overall do you think this has helped you?

I think so yeah

In what ways?

Um I'm it's just that I know I'm more confident of where to look at and I'm more consistent with like everyone I watch whereas like when I'm judging if I'm looking at different things with different people then I'm going to notice different things whereas now I'm much more constant with what I think I'm looking at based on the DVD sort of thing,

Ok so do you thinks that going to help you with the real life judging?

Yeah , I'm just more consistent so I'm not noticing different things on different people, if I'm looking at the same bits then it's fairer really

Do you think there are any problems with the intervention?

Um not really no,

Ok, thank you very much

APPENDIX 13: SPSS OUTPUT – (STUDY 4)

General Linear Model – number of fixations

Within-Subjects Factors

Measure: number

time	Dependent Variable
1	nobase
2	nopost
3	noret

Between-Subjects Factors

		Value Label	N
group	1.00	experimental	3
	2.00	control	2

Descriptive Statistics

	group	Mean	Std. Deviation	N
nobase	experimental	.6533	.06110	3
	control	.5800	.02828	2
	Total	.6240	.06066	5
nopost	experimental	.2800	.06928	3
	control	.4800	.11314	2
	Total	.3600	.13266	5
noret	experimental	.2667	.12220	3
	control	.5600	.00000	2
	Total	.3840	.18243	5

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Pillai's Trace	.954	20.905[b]	2.000	2.000	.046	.954	41.811	.666
	Wilks' Lambda	.046	20.905[b]	2.000	2.000	.046	.954	41.811	.666
	Hotelling's Trace	20.905	20.905[b]	2.000	2.000	.046	.954	41.811	.666
	Roy's Largest Root	20.905	20.905[b]	2.000	2.000	.046	.954	41.811	.666
time * group	Pillai's Trace	.926	12.562[b]	2.000	2.000	.074	.926	25.124	.493
	Wilks' Lambda	.074	12.562[b]	2.000	2.000	.074	.926	25.124	.493
	Hotelling's Trace	12.562	12.562[b]	2.000	2.000	.074	.926	25.124	.493
	Roy's Largest Root	12.562	12.562[b]	2.000	2.000	.074	.926	25.124	.493

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept+group
Within Subjects Design: time

Mauchly's Test of Sphericity[b]

Measure: number

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Epsilon[a] Huynh-Feldt	Epsilon[a] Lower-bound
time	.889	.236	2	.889	.900	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept+group
Within Subjects Design: time

Tests of Within-Subjects Effects

Measure: number

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Sphericity Assumed	.158	2	.079	22.723	.002	.883	45.446	.996
	Greenhouse-Geisser	.158	1.800	.088	22.723	.003	.883	40.902	.992
	Huynh-Feldt	.158	2.000	.079	22.723	.002	.883	45.446	.996
	Lower-bound	.158	1.000	.158	22.723	.018	.883	22.723	.873
time * group	Sphericity Assumed	.087	2	.044	12.569	.007	.807	25.138	.933
	Greenhouse-Geisser	.087	1.800	.048	12.569	.010	.807	22.625	.905
	Huynh-Feldt	.087	2.000	.044	12.569	.007	.807	25.138	.933
	Lower-bound	.087	1.000	.087	12.569	.038	.807	12.569	.662
Error(time)	Sphericity Assumed	.021	6	.003					
	Greenhouse-Geisser	.021	5.400	.004					
	Huynh-Feldt	.021	6.000	.003					
	Lower-bound	.021	3.000	.007					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: number

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Linear	.099	1	.099	40.593	.008	.931	40.593	.980
	Quadratic	.058	1	.058	12.992	.037	.812	12.992	.675
time * group	Linear	.081	1	.081	33.000	.010	.917	33.000	.955
	Quadratic	.006	1	.006	1.444	.316	.325	1.444	.138
Error(time)	Linear	.007	3	.002					
	Quadratic	.013	3	.004					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: number
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	3.181	1	3.181	240.173	.001	.988	240.173	1.000
group	.071	1	.071	5.328	.104	.640	5.328	.361
Error	.040	3	.013					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: number

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
.470	.030	.373	.567

4. group * time

Measure: number

group	time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
experimental	1	.653	.030	.557	.750
	2	.280	.050	.121	.439
	3	.267	.058	.083	.450
control	1	.580	.037	.462	.698
	2	.480	.061	.286	.674
	3	.560	.071	.335	.785

```
T-TEST
  GROUPS = group(1 2)
  /MISSING = ANALYSIS
  /VARIABLES = nobase nopost noret
  /CRITERIA = CI(.95) .
```

T-Test

```
[DataSet1] N:\study's 4 and 5\all data.sav
```

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
nobase	experimental	3	.6533	.06110	.03528
	control	2	.5800	.02828	.02000
nopost	experimental	3	.2800	.06928	.04000
	control	2	.4800	.11314	.08000
noret	experimental	3	.2667	.12220	.07055
	control	2	.5600	.00000	.00000

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
nobase	Equal variances assumed	1.396	.323	1.530	3	.223	.07333	.04792	-.07917	.22584
	Equal variances not assumed			1.808	2.894	.172	.07333	.04055	-.05843	.20510
nopost	Equal variances assumed	2.400	.219	-2.535	3	.085	-.20000	.07888	-.45103	.05103
	Equal variances not assumed			-2.236	1.515	.194	-.20000	.08944	-.73067	.33067
noret	Equal variances assumed	4.615	.121	-3.220	3	.049	-.29333	.09108	-.58320	-.00346
	Equal variances not assumed			-4.158	2.000	.053	-.29333	.07055	-.59690	.01023

General Linear Model – fixation durations

Within-Subjects Factors

Measure: duration

time	Dependent Variable
1	durbase
2	durpost
3	durret

Between-Subjects Factors

		Value Label	N
group	1.00	experimental	3
	2.00	control	2

Descriptive Statistics

	group	Mean	Std. Deviation	N
durbase	experimental	90.5873	15.69810	3
	control	79.2660	14.67162	2
	Total	86.0588	14.67927	5
durpost	experimental	54.3556	5.85161	3
	control	96.3528	8.89314	2
	Total	71.1545	23.79122	5
durret	experimental	49.2372	14.55398	3
	control	81.3128	5.94818	2
	Total	62.0674	20.57687	5

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Pillai's Trace	.827	4.779[b]	2.000	2.000	.173	.827	9.558	.252
	Wilks' Lambda	.173	4.779[b]	2.000	2.000	.173	.827	9.558	.252
	Hotelling's Trace	4.779	4.779[b]	2.000	2.000	.173	.827	9.558	.252
	Roy's Largest Root	4.779	4.779[b]	2.000	2.000	.173	.827	9.558	.252
time * group	Pillai's Trace	.830	4.877[b]	2.000	2.000	.170	.830	9.754	.256
	Wilks' Lambda	.170	4.877[b]	2.000	2.000	.170	.830	9.754	.256
	Hotelling's Trace	4.877	4.877[b]	2.000	2.000	.170	.830	9.754	.256
	Roy's Largest Root	4.877	4.877[b]	2.000	2.000	.170	.830	9.754	.256

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept+group
Within Subjects Design: time

Mauchly's Test of Sphericity[b]

Measure: duration

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.701	.709	2	.701	.770	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+group
Within Subjects Design: time

Tests of Within-Subjects Effects

Measure: duration

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Sphericity Assumed	927.057	2	463.528	3.598	.094	.545	7.197	.445
	Greenhouse-Geisser	927.057	1.540	601.910	3.598	.117	.545	5.542	.367
	Huynh-Feldt	927.057	2.000	463.528	3.598	.094	.545	7.197	.445
	Lower-bound	927.057	1.000	927.057	3.598	.154	.545	3.598	.266
time * group	Sphericity Assumed	1929.839	2	964.920	7.491	.023	.714	14.982	.758
	Greenhouse-Geisser	1929.839	1.540	1252.987	7.491	.039	.714	11.537	.645
	Huynh-Feldt	1929.839	2.000	964.920	7.491	.023	.714	14.982	.758
	Lower-bound	1929.839	1.000	1929.839	7.491	.072	.714	7.491	.467
Error(time)	Sphericity Assumed	772.887	6	128.814					
	Greenhouse-Geisser	772.887	4.621	167.271					
	Huynh-Feldt	772.887	6.000	128.814					
	Lower-bound	772.887	3.000	257.629					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: duration

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Linear	926.851	1	926.851	11.719	.042	.796	11.719	.634
	Quadratic	.205	1	.205	.001	.975	.000	.001	.050
time * group	Linear	1129.976	1	1129.976	14.287	.032	.826	14.287	.712
	Quadratic	799.863	1	799.863	4.480	.125	.599	4.480	.315
Error(time)	Linear	237.274	3	79.091					
	Quadratic	535.613	3	178.538					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: duration
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	81400.718	1	81400.718	450.709	.000	.993	450.709	1.000
group	1575.099	1	1575.099	8.721	.060	.744	8.721	.521
Error	541.818	3	180.606					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: duration

Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
75.185	3.541	63.915	86.456

4. group * time

Measure: duration

group	time	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
experimental	1	90.587	8.870	62.359	118.816
	2	54.356	4.049	41.469	67.242
	3	49.237	7.142	26.510	71.965
control	1	79.266	10.864	44.693	113.839
	2	96.353	4.959	80.570	112.136
	3	81.313	8.747	53.477	109.148

T-Test

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
durbase	experimental	3	90.5873	15.69810	9.06330
	control	2	79.2660	14.67162	10.37440
durpost	experimental	3	54.3556	5.85161	3.37843
	control	2	96.3528	8.89314	6.28840
durret	experimental	3	49.2372	14.55398	8.40274
	control	2	81.3128	5.94818	4.20600

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
durbase	Equal variances assumed	.190	.692	.807	3	.479	11.32133	14.02495	-33.31231	55.95498
	Equal variances not assumed			.822	2.408	.485	11.32133	13.77576	-39.29966	61.94232
durpost	Equal variances assumed	1.065	.378	-6.560	3	.007	-41.99720	6.40249	-62.37277	-21.62163
	Equal variances not assumed			-5.883	1.594	.046	-41.99720	7.13847	-81.56757	-2.42683
durret	Equal variances assumed	1.925	.259	-2.841	3	.066	-32.07560	11.29180	-68.01115	3.85995
	Equal variances not assumed			-3.414	2.779	.047	-32.07560	9.39662	-63.37222	-.77898

General Linear Model – number of areas

Within-Subjects Factors

Measure: areas

time	Dependent Variable
1	areasbase
2	areaspost
3	areasret

Between-Subjects Factors

		Value Label	N
group	1.00	experimental	3
	2.00	control	2

Descriptive Statistics

	group	Mean	Std. Deviation	N
areasbase	experimental	.6000	.06928	3
	control	.5200	.05657	2
	Total	.5680	.07155	5
areaspost	experimental	.2267	.04619	3
	control	.5200	.22627	2
	Total	.3440	.19920	5
areasret	experimental	.2000	.14422	3
	control	.5000	.02828	2
	Total	.3200	.19391	5

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Pillai's Trace	.824	4.670[b]	2.000	2.000	.176	.824	9.341	.248
	Wilks' Lambda	.176	4.670[b]	2.000	2.000	.176	.824	9.341	.248
	Hotelling's Trace	4.670	4.670[b]	2.000	2.000	.176	.824	9.341	.248
	Roy's Largest Root	4.670	4.670[b]	2.000	2.000	.176	.824	9.341	.248
time * group	Pillai's Trace	.810	4.262[b]	2.000	2.000	.190	.810	8.524	.232
	Wilks' Lambda	.190	4.262[b]	2.000	2.000	.190	.810	8.524	.232
	Hotelling's Trace	4.262	4.262[b]	2.000	2.000	.190	.810	8.524	.232
	Roy's Largest Root	4.262	4.262[b]	2.000	2.000	.190	.810	8.524	.232

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept+group
Within Subjects Design: time

Mauchly's Test of Sphericity[b]

Measure: areas

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.981	.038	2	.981	.982	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+group
Within Subjects Design: time

Tests of Within-Subjects Effects

Measure: areas

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Sphericity Assumed	.127	2	.064	6.728	.029	.692	13.456	.711
	Greenhouse-Geisser	.127	1.963	.065	6.728	.030	.692	13.210	.704
	Huynh-Feldt	.127	2.000	.064	6.728	.029	.692	13.456	.711
	Lower-bound	.127	1.000	.127	6.728	.081	.692	6.728	.431
time * group	Sphericity Assumed	.114	2	.057	6.006	.037	.667	12.011	.661
	Greenhouse-Geisser	.114	1.963	.058	6.006	.038	.667	11.791	.653
	Huynh-Feldt	.114	2.000	.057	6.006	.037	.667	12.011	.661
	Lower-bound	.114	1.000	.114	6.006	.092	.667	6.006	.396
Error(time)	Sphericity Assumed	.057	6	.009					
	Greenhouse-Geisser	.057	5.890	.010					
	Huynh-Feldt	.057	6.000	.009					
	Lower-bound	.057	3.000	.019					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: areas

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Linear	.106	1	.106	10.309	.049	.775	10.309	.584
	Quadratic	.021	1	.021	2.471	.214	.452	2.471	.200
time * group	Linear	.087	1	.087	8.439	.062	.738	8.439	.509
	Quadratic	.027	1	.027	3.113	.176	.509	3.113	.238
Error(time)	Linear	.031	3	.010					
	Quadratic	.026	3	.009					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: areas
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	2.635	1	2.635	146.516	.001	.980	146.516	1.000
group	.105	1	.105	5.861	.094	.661	5.861	.388
Error	.054	3	.018					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: areas

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
.428	.035	.315	.540

4. group * time

Measure: areas

group	time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
experimental	1	.600	.038	.480	.720
	2	.227	.079	-.023	.477
	3	.200	.069	-.018	.418
control	1	.520	.046	.373	.667
	2	.520	.096	.214	.826
	3	.500	.084	.232	.768

T-Test

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
areasbase	experimental	3	.6000	.06928	.04000
	control	2	.5200	.05657	.04000
areaspost	experimental	3	.2267	.04619	.02667
	control	2	.5200	.22627	.16000
areasret	experimental	3	.2000	.14422	.08327
	control	2	.5000	.02828	.02000

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
areasbase	Equal variances assumed	.600	.495	1.342	3	.272	.08000	.05963	-.10976	.26976
	Equal variances not assumed			1.414	2.667	.263	.08000	.05657	-.11345	.27345
areaspost	Equal variances assumed	117.600	.002	-2.363	3	.099	-.29333	.12413	-.68836	.10169
	Equal variances not assumed			-1.808	1.056	.311	-.29333	.16221	-2.11351	1.52685
areasret	Equal variances assumed	3.621	.153	-2.764	3	.070	-.30000	.10853	-.64538	.04538
	Equal variances not assumed			-3.503	2.223	.062	-.30000	.08563	-.63525	.03525

General Linear Model – outcome judgment

Within-Subjects Factors

Measure: scores

time	Dependent Variable
1	scorebase
2	scorepost
3	scoreret

Between-Subjects Factors

		Value Label	N
group	1.00	experimental	3
	2.00	control	2

Descriptive Statistics

	group	Mean	Std. Deviation	N
scorebase	experimental	1.1533	.38799	3
	control	1.4900	.35355	2
	Total	1.2880	.37486	5
scorepost	experimental	.7600	.50000	3
	control	1.7100	.38184	2
	Total	1.1400	.65742	5
scoreret	experimental	.7133	.52205	3
	control	1.2900	.63640	2
	Total	.9440	.58076	5

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Pillai's Trace	.406	.684[b]	2.000	2.000	.594	.406	1.368	.082
	Wilks' Lambda	.594	.684[b]	2.000	2.000	.594	.406	1.368	.082
	Hotelling's Trace	.684	.684[b]	2.000	2.000	.594	.406	1.368	.082
	Roy's Largest Root	.684	.684[b]	2.000	2.000	.594	.406	1.368	.082
time * group	Pillai's Trace	.817	4.455[b]	2.000	2.000	.183	.817	8.911	.240
	Wilks' Lambda	.183	4.455[b]	2.000	2.000	.183	.817	8.911	.240
	Hotelling's Trace	4.455	4.455[b]	2.000	2.000	.183	.817	8.911	.240
	Roy's Largest Root	4.455	4.455[b]	2.000	2.000	.183	.817	8.911	.240

a. Computed using alpha = .05

b. Exact statistic

c.

Design: Intercept+group
Within Subjects Design: time

Mauchly's Test of Sphericity[b]

Measure: scores

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.257	2.718	2	.257	.574	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept+group
Within Subjects Design: time

Tests of Within-Subjects Effects

Measure: scores

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Sphericity Assumed	.263	2	.131	1.070	.400	.263	2.141	.162
	Greenhouse-Geisser	.263	1.147	.229	1.070	.382	.263	1.228	.123
	Huynh-Feldt	.263	2.000	.131	1.070	.400	.263	2.141	.162
	Lower-bound	.263	1.000	.263	1.070	.377	.263	1.070	.116
time * group	Sphericity Assumed	.229	2	.115	.933	.444	.237	1.867	.147
	Greenhouse-Geisser	.229	1.147	.200	.933	.413	.237	1.071	.114
	Huynh-Feldt	.229	2.000	.115	.933	.444	.237	1.867	.147
	Lower-bound	.229	1.000	.229	.933	.405	.237	.933	.107
Error(time)	Sphericity Assumed	.737	6	.123					
	Greenhouse-Geisser	.737	3.442	.214					
	Huynh-Feldt	.737	6.000	.123					
	Lower-bound	.737	3.000	.246					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: scores

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Linear	.246	1	.246	1.382	.325	.315	1.382	.135
	Quadratic	.017	1	.017	.254	.649	.078	.254	.066
time * group	Linear	.035	1	.035	.194	.689	.061	.194	.062
	Quadratic	.195	1	.195	2.872	.189	.489	2.872	.224
Error(time)	Linear	.534	3	.178					
	Quadratic	.203	3	.068					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: scores
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	20.259	1	20.259	47.298	.006	.940	47.298	.990
group	1.389	1	1.389	3.242	.170	.519	3.242	.246
Error	1.285	3	.428					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: scores

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
1.186	.172	.637	1.735

4. group * time

Measure: scores

group	time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
experimental	1	1.153	.218	.461	1.846
	2	.760	.268	-.092	1.612
	3	.713	.325	-.321	1.747
control	1	1.490	.266	.642	2.338
	2	1.710	.328	.666	2.754
	3	1.290	.398	.024	2.556

APPENDIX 14: RELATED PUBLICATIONS

Page, J., Lafferty, M.E., & Wheeler, T. (2007). An exploration of visual search between coaches and judges in gymnastics. Paper presented at ECSS, Finland

Page, J., Lafferty, M.E., & Wheeler, T. (2007). The link between knowledge and visual fixations in gymnastics coaching and judging; a case study approach. Paper presented at FEPSAC, Greece

Abstract accepted

Page, J., Lafferty, M.E. & Holder, T. (2009). The development and effectiveness of a perceptual training programme for coaches and judges in gymnastics. To be presented at the 12th ISSP World Congress of Sport Psychology, Marrakesh